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Fusarium Disease of the Prickly Pear

By C. W. Carpenter

A destructive disease of the common prickly pear, generally known as "panini" in Hawaii, is discussed. The disease, first reported at Kekaha, Kauai, has been investigated in cooperation with the Territorial Board of Agriculture and Forestry, and the latter has approved the transmission of the causal agent, a fungus, to localities where the panini is a pest. Large and small panini plants have collapsed in from two to five weeks after inoculation with the parasitic fungus, a variety of Fusarium oxysporum.

A disease of the common prickly pear (*Opuntia megacantha*) which was reported to be very destructive at Kekaha Sugar Company, Ltd. was pointed out to several staff members of the Experiment Station, H.S.P.A. in November 1943, by L. A. Faye, Manager. Cladodes, usually referred to as pads or joints, of the affected plants were collected by Steven Au and submitted by D. T. Fullaway for diagnosis.

Various diseases of cacti have been reported rather extensively in literature but none appears identical with the disease discussed herein. The symptoms are not particularly distinctive—a progressive softening of the entire pad accompanied by a change of the normal green to gray and fuscous with ultimate collapse of the pad which falls to the ground. At times considerable exudate oozes from the ruptured surfaces and dries as a firm gum, and secondary rot organisms (bacteria) may hasten the destruction, often developing gas which swells the affected area.

Mr. Fullaway was advised to inoculate healthy plants with tissue and juice from the diseased material to determine if the disease was infectious. These direct inoculations and others made subsequently by him and by J. P. Martin and C. G. Lennox were positive in a sufficiently large percentage to establish the infectious nature of the disease.

In the meantime a *Fusarium* sp. (fungus) and two strains of bacteria were isolated in pure culture from the original specimens. Healthy pads, brought to the laboratory by Mr. Fullaway, were inoculated with the three organisms, separately, and in all combinations. Rotting, typical of the original material and of the direct inoculations, developed only when the Fusarium was present in the inoculum. In a subsequent experiment one hundred per cent positive results, secured from

Fig. 1. Upper and lower surfaces of two pads of prickly pear two weeks after inoculation with *Fusarium oxysporum* var. at three points on each pad (at the left). The dark, rotted area has almost reached the six control punctures. At the right, lower surfaces of the same pads.

inoculations of detached pads with the Fusarium, demonstrated that this fungus was capable of producing the symptoms (Figs. 1 and 2). Control inoculations made with sterile distilled water were uniformly without effect. Numerous inoculations

of twelve large and small pear plants growing on the slope of Punchbowl Crater were then made hypodermically with spore suspensions of pure cultures of the reisolated Fusarium; control inoculations with sterile distilled water were made at various points on four other plants. Within ten days it was evident that without exception

Fig. 2. The lower surface of an inoculated pad of prickly pear; the mycelium of *Fusarium oxysporum* var. has grown through the pad and formed spores.

the Fusarium had infected the pads at every inoculation point while at no time did the control inoculations show any sign of infection. In the majority of cases the pads inoculated with the Fusarium were in three weeks almost completely rotted and dropping off, while the smaller plants consisting of three to five pads were rotted to the ground.

McLaughlin (1) described a necrotic rot disease of *Cereus Schottii* occurring in Mexico and Arizona and concluded that it was caused by an undetermined variety of *Fusarium oxysporum*. Successful inoculations of *C. Schottii* and of a prickly pear of the Englemannii group were reported. Pasinetti and Buzzati-Traverso (2) discussed two species of Fusarium as wound parasites of cacti in Italy: *F. cactacearum* caused a basal dry rot of *Thelocactus nidulans* and *F. cacti-maxoni* similarly attacked *Cactus maxoni*. Another species apparently from cactus, *F. opuntiarum* Speg., was reduced to synonomy with *F. oxysporum* by Wollenweber and Reinking (3, p. 330).

The Fusarium in the present studies, observed to be at least a wound parasite of the prickly pear, was identified as a variety of *F. oxysporum* after growing it in pure culture on sterile cotton stems, Panicum culms, rice, and nutrient agar containing one-half per cent neopeptone (Difco). On the rice medium a faint

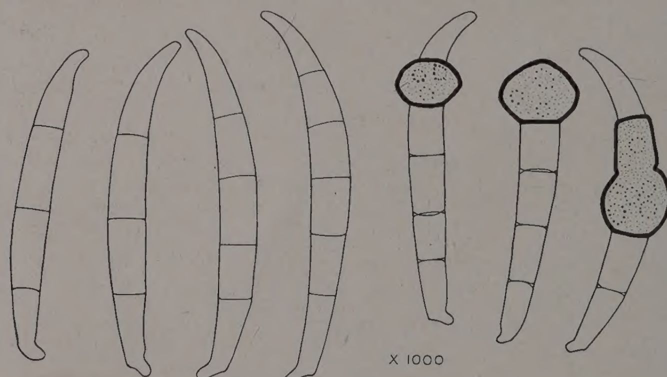

Fig. 3. Macroconidia and thick-walled resistant spores, conidio-chlamydospores, of *Fusarium oxysporum* var. Such spores are produced in abundance on the cactus as well as in cultures.

aromatic odor suggesting lilac, an odor characteristic of several species of the Section Elegans of the Genus Fusarium, was noticed. As mycologists well know, extensive and critical comparative studies are required to identify species and varieties in this difficult genus. In the present species as well as in most species of this genus the microconidia are of very slight diagnostic value; on the other hand the size and shape of the macroconidia from cultures in suitable stages of development are characteristic of the Sections and in many cases specifically of great diagnostic value. The macroconidia from pionnotes (spore slime) and sporodochia (fruiting bodies), illustrated in Fig. 3, are much larger than recorded by McLaughlin, being approximately three times as long in the case of the four-septate spores: 35–55 x 4.0–5.0 microns. Four-septate forms were common as was also recorded by McLaughlin. The rather meagre symptoms of the disease as recorded by the latter on an Opuntia species do not closely resemble those of the disease under study; this lack of harmony together with the difference in host plants and the great discrepancy in the size of the macroconidia of the Fusaria indicate that the two diseases are distinct.

The *Section Elegans* of the *Genus Fusarium* of which the local *F. oxysporum* var. is a member includes many important plant parasites which cause serious

wilt diseases, e.g., *F. oxysporum*, Irish potato wilt; *F. bulbigenum* var. *lycopersici*, tomato wilt; and *F. vasinfectum*, cotton wilt.

The prickly pear in Hawaii as well as elsewhere is an important forage plant in arid sections. In drought the tender young pads are the life-saving sources of succulent food and water for livestock. In some arid sections of Hawaii the prickly pear, and the dew and misty rains are such important sources, if not the only sources of water, that cattle are reported to reach maturity without learning to drink; they will take water only by lapping it from moist surfaces in the paddocks and in trans-channel shipment to market.

In more fertile sections of the Islands the prickly pear is a detested weed encroaching upon large areas of the best land and rendering them useless for cultivation or pasturage. In such localities any disease of the cactus is welcomed as a possible means of restricting its spread or of killing it. What ultimate effect the Fusarium disease may have on this plant in Hawaii cannot be foretold.

Literature Cited

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(3) Wollenweber, H. W., and Reinking, O. A., 1935. Die Fusarien. Paul Parey, Berlin, 1935, 355 pages.

Crop Relationships With Special Reference to Nitrogen Efficiency

By R. J. Borden

Six years of results from well-replicated nitrogen experiments have afforded data for a study of some of the involved relationships which can be useful in planning field practices, especially in judging the efficiency we are securing from applications of nitrogen fertilizer. Thus comparisons with some of their associations are offered between plant crops and ratoons, between different seasons of starting crops, of per-acre nitrogen applications, and of season and age at harvest. Yield groups are examined for differences which may be contributory factors and for evidence of their nitrogen utilization, and finally the suggested efficiency values in terms of nitrogen per month and per ton of cane are examined for confirmation of amounts previously indicated.

We are often asked for information concerned with the effects which various cropping practices can exert upon optimum sugar yields, and a specific answer is exceedingly difficult because of the large number of contributory factors which may not always be subject to identification and measurement. Perhaps then, if we could examine reliable data which have come from a sufficiently large number of well-distributed sugar cane areas, we might find in the averaged measurements which are involved, indications of some of the relationships we are looking for. The usefulness of such averaged measurements to the individual plantation man will be first in indicating what specific deviations occur in similar measurements in his records, and then in rationalizing reasons therefor. Thus they will focus his attention on certain figures which are related to an average criterion of efficiency, and lead him to look for the real cause of the larger deviations from this criterion which his records show. Some of the more obvious causes, such as differences in soils, sunshine, temperature, etc., will be easy to identify; others will be more difficult but should nevertheless be carefully looked for in the growth history of the crop concerned.

An opportunity to make a study of this nature has been found in a recent summary of all Grade A "Amounts-of-Nitrogen" experiments which have been reported to us from the 1937 to 1942 crops inclusive. We have records from 396 such tests, conducted with different cane varieties under widely different soil and climatic conditions from north Kauai to south Hawaii. From each one of these tests we have selected the data which are associated with that specific nitrogen treatment which produced the optimum sugar yield (as averaged from not less than seven replicates in each experiment), *i.e.*, that level or amount of nitrogen which produced the maximum proved response in tons of sugar per acre. Thus we have basic data which can be considered as examples of a large number of very creditable field yields, *i.e.*, creditable for the specific areas and conditions involved. Unfortunately, in 271 of

these experiments there was no proved increase in sugar yield for any amount of nitrogen greater than the minimum treatment used, so, for the purpose of this study, this minimum has had to be considered also as the optimum; this fact should be remembered in any analysis of the nitrogen efficiency values which are discussed hereafter.

Plant Crops vs. Ratoons:

One of the more commonly asked questions is that of the relationships between plant crops and ratoons. We have summarized some of these in Table I, and note several things which stand out therein. For instance, the plant crops were fully

TABLE I
PLANT VS. RATOON CROPS

Crops	No. of tests	Age at harvest (mos.)	Pounds of nitrogen Per acre	Pounds of nitrogen Per month	Yields TCA	Yields TCAM	Yields TSA	Yields TSAM	Pounds of nitrogen Per ton cane	Pounds of nitrogen Per ton sugar	TC/TS
Plant	119	21.4	147	7.0	87.0	4.1	9.5	.45	1.8	16.1	9.2
Ratoons*	277	19.1	147	8.0	63.3	3.4	6.7	.36	2.5	23.9	9.4

* Only 8 per cent older than third ratoons.

two months older than the ratoons and this may partly account for the fact that they have produced more cane and sugar per acre. Then, although it is indicated that both plant crops and ratoons have made their optimum sugar yields on the same average applications of nitrogen per acre (147 pounds), it is evident that the plant crops were more efficient users of their applied nitrogen and required it at the rate of one pound less per month. It can be assumed, however, that the plant crops received more nitrogen than the ratoons from the soil's natural nitrogen supplies.

The plant crops produced almost one-tenth of a ton of sugar per acre per month more than the ratoons, and their optimum yields were made with greater nitrogen efficiency since less than two pounds of nitrogen were needed per ton of cane grown, whereas the ratoons for their optimum sugar yield required two and a half pounds of nitrogen per ton of cane. A similar relationship is seen for nitrogen efficiency expressed in terms of pounds of nitrogen per ton of sugar.

It is doubtful that the differences in tons cane per ton sugar (TC/TS) are significant, although we might expect the increased age of the plant crops to account for a slightly better quality.

Season of Start:

It is impossible in a study from the data which were available to separate the effects of the season of starting the crops from the season of harvest. However, the data in Table II have been summarized for study and interpretation by the individual reader who has his own ideas of this effect.

We believe there is some foundation in these figures for some of the opinions that we have long held with regard to optimum starting seasons. Thus both the fall- and winter-started crops, which got underway slowly in the cooler soil temperatures during these seasons, never quite made up in their yields for their slower start and, on an equivalent time basis, they made cane and sugar at slightly lower rates per month than crops which were started in the spring and summer.

Apparently these fall-started crops also needed more of the applied nitrogen than crops started earlier. This could be due to their slower "closing in" and a subse-

quently longer period of competition with weeds for the nitrogen which is supplied. Or it could be because of reduced supplies of natural soil nitrogen when the micro-organisms in the cooler soil during this season become less active.

TABLE II

SEASON OF STARTING CROPS

Season	No. of tests	Avg. age (mos.)	TSA	TSAM	TCAM	Pounds of nitrogen: Per acre	Per month	Per ton cane	Per ton sugar
Winter (Jan., Feb., Mar.)	92	19.6	7.0	.36	3.5	138	7.1	2.2	21.3
Spring (Apr., May, June)	118	20.7	8.1	.39	3.6	147	7.3	2.1	19.8
Summer (July, Aug., Sept.)	121	19.7	8.1	.41	3.8	155	8.1	2.3	21.5
Fall (Oct., Nov., Dec.)	65	18.4	6.4	.36	3.4	146	8.4	2.6	25.5

Pounds of Nitrogen per Acre:

Although there is quite general agreement that a cane crop which is to be grown for only 15 or 16 months should actually need less nitrogen than one which will be nearer two years old at harvest, and that a 60-ton crop cannot efficiently use as much nitrogen as one which produces 100-ton cane, we still find a rather universal consideration of crop nitrogen needs on the basis of pounds per acre. Thus Table III has been prepared to show the relationships that are associated with those different amounts of nitrogen applied per acre that gave the optimum sugar yields in the experiments studied. The data are organized separately for both the plant and the ratoon crops.

TABLE III

POUNDS NITROGEN PER ACRE

	Nitrogen applied lbs./acre	No. of tests	TCA	TSA	Age (mos.)	TCAM	TSAM	Pounds of nitrogen: Per month	Per ton cane	Per ton sugar
Plant Crops:	100 or less	29	77.0	7.9	20.2	3.9	.39	4.6	1.2	12.0
	101–125 lbs.	16	79.8	8.6	21.9	3.6	.39	5.7	1.7	15.3
	126–150 lbs.	29	91.8	9.8	21.6	4.4	.46	7.0	1.7	16.2
	151–175 lbs.	20	95.8	10.8	21.9	4.4	.50	7.7	1.8	16.2
	176–200 lbs.	10	87.7	10.4	21.1	4.2	.50	9.5	2.3	19.4
	Over 200 lbs.*	15	92.5	10.7	22.2	4.2	.49	10.6	2.6	22.6
Ratoons:	100 or less	54	57.2	5.4	18.2	3.2	.30	4.8	1.7	18.2
	101–125 lbs.	46	61.1	6.5	19.0	3.3	.35	6.6	2.1	20.5
	126–150 lbs.	78	61.7	6.4	18.5	3.5	.36	8.5	2.6	25.8
	151–175 lbs.	43	68.4	7.4	19.6	3.6	.38	8.9	2.6	25.6
	176–200 lbs.	34	67.4	8.1	20.8	3.3	.39	9.6	3.1	27.0
	Over 200 lbs.†	24	71.9	8.2	19.4	3.7	.42	12.0	3.4	31.2

* Average 233 pounds. † Average 230 pounds.

For plant crops there appears to have been no advantage for nitrogen applications greater than 150 to 175 pounds per acre, for a crop harvested at about 22 months. The higher rates per acre are clearly responsible for increased nitrogen expenditures per month, per ton of cane, and per ton of sugar. For ratoons, however, even though they were harvested at perhaps two months younger, there are indications* that the per-acre application of nitrogen might be somewhat higher than

* We use the word "indications" advisedly here because in eight of the 24 ratoon crops which received over 200 pounds N per acre, the actual amount used was the minimum amount included in the experiment concerned.

175 pounds per acre, for even though the two larger per-acre applications resulted in the use of larger amounts per month and per ton of cane and sugar, they were not proved inefficient in view of their beneficial effect on the sugar yields.

Season of Harvest (See Table IV):

Crops that were harvested during the summer season have given lower yields of cane and sugar, and have made cane and sugar at slower rates per month than crops taken off at other times. Fall-harvested crops have made cane at a slightly higher rate per month but these have given relatively poorer sugar yields than winter- or spring-harvested crops because of poorer quality; this may be partly due to their younger age at harvest but it is not unlikely that the influence of sucker growth, which is prevalent in fall-harvested cane, is also a contributory factor. Spring harvesting, because of its better cane quality, is undoubtedly the most desirable.

Efficient nitrogen utilization has not been significantly different except for nitrogen per month for the fall-harvested crops, and this may be because many short ratoons are included in this group.

TABLE IV

SEASON OF HARVEST

Season	No. of tests	TCA	TSA	TC/TS	Age (mos.)	TCAM	TSAM	Pounds of nitrogen: Per acre	Per month	Per ton cane	Per ton sugar
Winter (Jan., Feb., Mar.)	93	77.1	8.3	9.3	20.3	3.8	.41	155	7.7	2.2	19.9
Spring (Apr., May, June)	111	73.1	8.2	8.8	20.3	3.6	.41	152	7.6	2.3	21.1
Summer (July, Aug., Sept.)	128	63.7	6.7	9.4	19.9	3.2	.34	139	7.3	2.4	23.1
Fall (Oct., Nov., Dec.)	64	73.0	6.9	10.5	17.8	4.1	.39	146	8.4	2.1	21.9

Age at Harvest:

In the four groups which are summarized in Table V, the influence of the age of the crop at harvest is definitely seen in the increases of both TCA and TSA, and in the improved juice quality (TC/TS).

Monthly nitrogen utilization appears to be high for the youngest age group, but this could be due to the fact that its actual minimum requirements were somewhat less than the plan of its specific tests was able to identify. However, there does appear to be a trend towards a lower monthly utilization of nitrogen as the crop age is increased. Again, except for this youngest age group, there is little difference between the other three groups in their nitrogen utilization per ton of cane or sugar. This similarity may indicate that total nitrogen applications which are based on a well-estimated cane tonnage, which in turn is also influenced by its expected age at harvest, should prove to be efficient and quite reliable; and the actual figure would not appear to be far from two pounds of nitrogen for each ton of cane.

TABLE V

AGE AT HARVEST

Age group	No. of tests	TCA	TSA	Pounds of nitrogen: Per acre	Per month	Per ton cane	Per ton sugar	TC/TS
Under 15 months..	38	52.0	5.2	149	11.1	3.03	30.2	10.0
15 to 18 months...	130	64.0	6.5	133	7.9	2.20	21.8	9.8
19 to 22 months...	137	74.3	8.1	152	7.3	2.16	20.5	9.2
Over 22 months...	91	81.6	9.3	158	6.5	2.10	19.3	8.8

Cane and Sugar Yields:

A breakdown of the average yields which were secured from the optimum treatment, that was indicated in each Grade A experiment included in this study, is given in Table VI. The eight groupings of TCA and the seven groups of TSA figures which are presented show certain interesting relationships: (1) An excellent positive and almost linear relationship is shown between the cane and the sugar yields; (2) both groups show their higher yields to be associated more directly with plant crops than with ratoons and, conversely, their lower yields to have come largely from ratoons; (3) increased yields were positively associated with increases in the age of the crops at harvest; and (4) positive correlations exist between the actual yields and the monthly rates at which both cane and sugar were produced.

With one exception (the 7.0–7.9 TSA group) the nitrogen efficiency values follow a definite pattern. Thus we find an increased use of nitrogen per acre, but a decreased utilization of nitrogen, both per ton of cane and of sugar, to be associated with the increases in yields of cane and sugar. About the only figure which does not materially change with each successive increase in the yield is that for pounds of nitrogen per month; this stays pretty close to 7.5 and only in the one exception noted does it go above 8.0.

TABLE VI

CANE AND SUGAR YIELDS

Tons cane/acre	TSA	Number of: Plant crops	Ratoons	Age (mos.)	TCAM	TSAM	Pounds of nitrogen: Per acre	Per ton cane	Per ton sugar	Per month
Under 40	3.4	1	18	17.1	2.1	.20	127	3.9	42.3	7.7
40–49	4.8	4	41	17.4	2.7	.28	133	2.9	28.9	7.9
50–59	6.2	5	61	18.3	3.1	.34	140	2.6	24.2	7.9
60–69	7.1	14	60	19.7	3.4	.36	143	2.2	21.3	7.5
70–79	8.2	21	55	20.1	3.8	.41	155	2.1	19.0	7.8
80–89	9.3	25	25	20.8	4.2	.45	156	1.9	17.2	7.6
90–99	10.1	18	11	22.5	4.2	.45	163	1.7	16.6	7.3
Over 99	12.3	31	6	22.4	5.1	.55	158	1.4	13.0	7.1
Tons sugar/acre	**TCA**									
Under 5.0	46.0	2	56	17.5	2.6	.24	131	3.2	35.4	7.8
5.0–5.9	59.2	5	54	18.5	3.2	.31	134	2.4	24.3	7.5
6.0–6.9	65.1	13	52	18.6	3.5	.36	133	2.2	20.7	7.4
7.0–7.9	72.1	13	44	19.5	3.7	.39	157	2.3	21.2	8.3
8.0–8.9	78.2	20	29	20.6	3.8	.42	148	1.9	17.5	7.4
9.0–9.9	86.1	18	20	21.0	4.1	.46	153	1.9	16.3	7.5
Over 9.9	100.3	47	23	22.8	4.4	.53	172	1.8	14.6	7.6

Tons of Sugar per Acre per Month:

Because the age at which cane crops are harvested has such an important effect upon the yields, we have become accustomed to making many comparisons on the basis of sugar per acre per month. So for our next table (No. VII) we have arranged our data separately from plant crops and ratoons to show the relationships associated with specific TSAM groupings.

Since the optimum sugar yields recorded from 396 experiments are represented in Table VII, we should find some important associated nitrogen relationships therein. We do find that the 35 plant crops which made sugar at more than .50 TSAM used efficiently therefor an average of 173 pounds of nitrogen per acre, and produced an average of 107.4 tons of cane per acre in a period of 20.9 months. These excellent performances give us nitrogen efficiency values of 8.3 pounds of nitrogen per month, of 1.7 pounds of nitrogen per ton of cane, and of 14.6 pounds of nitrogen per ton of sugar.

At the same time, the 26 ratoon crops which performed better than .50 TSAM did so on practically the same amount of nitrogen per acre as the plant crops, *i.e.*, 175 pounds, but they were two months younger at harvest and made only 83.7 tons of cane per acre. Thus the nitrogen efficiency values for these ratoons were somewhat higher, *viz.*, 9.6 pounds per month, 2.1 pounds per ton of cane, and 17.4 pounds per ton of sugar. It is of interest that 13 of these 26 crops were short ratoons averaging in actual age only 15½ months, and their average production was .56 TSAM.

TABLE VII

TONS SUGAR PER ACRE PER MONTH (TSAM)

	TSAM	No. of tests	TCA	Age (mos.)	Pounds of nitrogen: Per acre	Per month	Per ton cane	Per ton sugar
Plant Crops:	Under .25	3	69.0	25.1	133	5.3	2.1	25.5
	.25–.29	6	63.4	22.3	143	6.2	2.2	22.8
	.30–.34	12	71.8	24.3	135	5.6	2.0	16.8
	.35–.39	17	74.8	21.4	117	5.6	1.6	15.2
	.40–.44	24	80.3	20.1	132	6.6	1.7	15.7
	.45–.50	22	88.5	21.3	156	7.5	1.8	15.8
	Over .50*	35	107.4	20.9	173	8.3	1.7	14.6
Ratoons:	Under .25	40	47.2	20.9	134	6.5	3.1	35.6
	.25–.29	44	54.9	20.0	137	7.1	2.6	26.6
	.30–.34	40	58.5	18.1	135	7.6	2.4	24.2
	.35–.39	50	67.0	19.0	147	7.9	2.3	21.3
	.40–.44	43	69.9	18.6	152	8.4	2.2	20.0
	.45–.50	34	69.8	17.8	164	9.5	2.4	20.4
	Over .50†	26	83.7	18.8	175	9.6	2.1	17.4

* Average .58. † Average .55.

Pounds of Nitrogen per Month:

There have been occasional discussions among plantation agriculturists about the value of a figure for pounds of nitrogen per acre per month of growing time to be allowed, which might be used in estimating total crop nitrogen requirements, and subconsciously this idea has generally influenced decisions of amounts per acre to be applied. Specifically, however, it is doubtful whether this figure has heretofore been determined with sufficient accuracy to make its use dependable.

In Table VIII our data have been arranged to show various relationships with "pounds of nitrogen per month." There is little to indicate that the returns have significantly improved where each acre received nitrogen at a rate of more than eight pounds per month. Although it appears that a slightly better performance in terms of TSAM was obtained, and from a younger and smaller cane crop too, when this rate was more than 10 pounds per month, we cannot place too much reliance upon this interpretation because in 22 of the 63 experiments concerned, this high figure comes from the minimum amount of nitrogen which was not actually proved to be the optimum; without these 22 tests the average TSAM figure associated with "more than 9.9 pounds N/mo." (actually an average of 12.2 pounds per month) becomes only .40. However, there may be an interaction here with the age of the crop at harvest which has not been identified and which needs further study.

TABLE VIII

POUNDS OF NITROGEN PER MONTH

Nitrogen applied: Pounds per month	No. of tests	TCA	TSA	Avg. age (mos.)	TCAM	TSAM	Average pounds nitrogen Per acre	Per ton cane	Per ton sugar
Less than 5.0*	59	68.8	6.6	21.5	3.2	.31	88	1.4	14.4
5.0 to 5.9	47	68.6	7.0	20.8	3.3	.34	113	1.8	18.2
6.0 to 6.9	65	73.5	7.8	21.0	3.5	.36	137	2.1	20.3
7.0 to 7.9	54	72.9	7.9	19.7	3.7	.40	147	2.2	19.6
8.0 to 8.9	63	74.9	7.8	19.7	3.8	.40	166	2.4	22.4
9.0 to 9.9	45	72.6	7.9	19.1	3.8	.42	180	2.6	24.9
More than 9.9†	63	66.4	7.1	16.6	4.0	.43	197	3.2	30.7

* Average 4.1. † Average 12.1.

Pounds of Nitrogen per Ton of Cane:

Still another measurement that has been considered for guidance in the total nitrogen allowance for a cane crop is one that is based upon the expected cane tonnage that will be produced. From their previous experience, fieldmen are able to make fairly reliable estimates of what their cane yields should be. Hence if we could set a reliable figure for nitrogen requirements on the basis of pounds of nitrogen per ton of cane, we should not stray very far from efficiency in its use.

In Table IX the data which are presented indicate that the better performances have come from those crops which received nitrogen at the lower levels per ton of cane harvested; in fact, the average results from applications of less than two pounds of nitrogen per ton of cane have been quite good. Evidently other growth factors than nitrogen were responsible for the poorer yield performance and the greater expenditures of nitrogen per acre, per month, or per ton of sugar. Hence attempts to increase sugar yields by supplying nitrogen at amounts much higher than two pounds per ton of cane are not likely to be successful.

TABLE IX

POUNDS OF NITROGEN PER TON OF CANE

Nitrogen applied: Pounds per ton cane	No. of tests	TCA	TSA	Age (mos.)	TCAM	TSAM	Average pounds nitrogen Per acre	Per month	Per ton sugar
Less than 1.5*	68	91.5	9.3	20.8	4.4	.44	104	5.0	11.5
1.5 to 1.9	93	78.8	8.0	20.2	3.9	.40	132	6.7	16.9
2.0 to 2.4	102	71.3	7.7	19.8	3.6	.39	153	7.9	20.5
2.5 to 2.9	65	63.7	6.9	19.3	3.3	.37	163	8.7	24.7
3.0 to 3.4	32	58.5	6.4	19.5	3.0	.33	180	9.4	29.6
More than 3.4	36	48.9	5.0	18.1	2.7	.29	195	11.4	43.0

* Average 1.2.

Summary:

In attempting to build up a background of experience and to find certain criteria which can be used to judge relative performances and efficiency in sugar cane agriculture, we have studied the records from the optimum treatment of a large number of field experiments. From these tests certain crop relationships have been identified, and the more important of these may be summarized as follows:

1. Plant crops produced higher yields than ratoons.

2. Plant crops made more efficient use of applied nitrogen fertilizers.

3. Crops started in October, November, and December produced poorer yields and were less efficient in their use of nitrogen.

4. Nitrogen supplied at 150 to 175 pounds per acre was adequate for plant crops and at this rate was efficiently used. For ratoons, slightly larger per acre amounts were indicated.

5. Harvesting from January to June was indicated as most desirable; July to September harvests gave disappointingly low yields.

6. Improved juice quality and higher yields of cane and sugar followed from increases in the age at harvest.

7. An almost linear relation was found between the cane and the sugar yields.

8. A higher nitrogen requirement per acre, but less per ton of cane and sugar, was associated with increases in yields, but nitrogen-per-month values were quite constant regardless of changes in yields.

9. Nitrogen efficiency values from those crops which had the best performance records (as TSAM) were as follows:

Crops	lbs. N/acre	lbs. N/month	lbs. N/ton cane	lbs. N/ton sugar
Plant	173	8.3	1.7	14.6
Ratoons	175	9.6	2.1	17.4

10. The highest nitrogen efficiency values are actually indicated as being about eight pounds per month, and at about two pounds per ton of cane.

Rat-trapping Records Show Effectiveness of Control Methods

By R. E. Doty

Data from trapping records over a period of five years are presented as a basis of evaluating the efficiency of the prebaited feeding-station method of rat control in sugar cane fields of Hawaii.

These data show the high degree of efficiency that can be attained by systematic and continuous rat-control measures.

The object of this study was to obtain information on the efficiency of the prebaited feeding-station method of rat control by the use of systematic trapping following the regular prebaiting and poisoning rounds.

It was also desirable to determine the relative densities of the rat population through the different seasons of the year, as well as the density that will probably continue to be maintained even under systematic and effective prebaiting and poisoning practices which result in very little rat-damaged cane at harvest.

This method of rat control has been adequately described by the writer in *The Hawaiian Planters' Record,* 42: 39–76, 1938. Briefly, it makes use of portable, covered feeding stations which are placed at strategic points and baited with loose unpoisoned grain for from five to six days to establish confidence in focal points of good feeding grounds for the rats in the vicinity. When rat suspicion of this new food supply has been overcome and the take of bait indicates considerable activity, a quick change to a bait which is similar in all respects except that a poison has been added will result in a good acceptance of the poisoned grain before the rats suspect that it has been changed.

Following each round of poison, approximately once in every three months, an index of the remaining rat population was secured by setting out ordinary spring traps baited with chunks of coconut.

The work was carried on at the Kauai Variety Station in 18.2 acres of cane land, which is a part of Field 19 Hanamaulu, of The Lihue Plantation Company, Ltd. This area is adjacent to the county road and in the heart of a large area of cane land. A small side branch of Wailua gulch extends up into one side of the area, thus exposing the Variety Station's cane to rat reinfestation from a large area of wasteland.

Prior to the prebait control program which began in August 1938, this area was heavily infested with rats and damage to cane crops was extremely serious, being especially severe along the field edges next to the wasteland. Trapping, torpedo poisoning, and experimental prebaiting were carried on during the latter half of 1937 and the first half of 1938. These control measures were not entirely satisfactory as this small area of cane was almost immediately reinfested with rats.

Lihue Plantation began prebaiting work on a small scale in January 1938. In August 1938 a cooperative arrangement was inaugurated between Lihue Plantation and Kauai Variety Station by which the plantation would prebait and poison the Variety Station area at the same time as their entire surrounding cane area. In return the station staff would trap and record the catch of rats from 100 traps per day, spaced over the 18.2 acres, during the period between the prebaiting rounds.

We now have an almost continuous trapping record for 100 traps per day in this 18.2 acres of cane for a period of five years and five months (August 25, 1938, to January 25, 1944), and it is the purpose of this report to bring together all data relating to this study and to make such compilations, graphs, and comments as seem to be warranted.

Rat Population at Kauai Variety Station Before Systematic Prebaiting and Poisoning Became Routine Practice

H. K. Stender reported in at least two of his monthly reports (August and September 1938) that before the first Lihue Plantation prebaiting, August 1938, trapping work yielded around eight rats per 100 traps per day. The records of intermittent trapping of rats at the Variety Station during the months of April to August 1938 inclusive, while various control measures were being tried, show the following interesting figures:

TABLE I

TRAPPING RECORDS BEFORE PREBAITING

Year and month	Average rats caught per 100-trap days
1938:	
April	5.2
May	6.4
June	6.9
July	5.8
August	9.7
Total	34.0
Average	6.8

Comments in reports by Mr. Stender* during this period indicated that cane damage was continuing.

Rat Population at Kauai Variety Station During the Period of Systematic Prebaiting—August 25, 1938, to January 25, 1944

The records of rats trapped during this period have been tabulated and summarized. Table II gives the detailed data by months, with yearly totals showing: (1) number of days 100 traps were set; (2) total rats caught; and (3) average number of rats per 100 traps per day. Table III shows the average number of rats caught per 100 traps per day, by months with the five-year average.

By plotting the average number of rats caught per 100 traps for the months from April to August 1938 inclusive (previous to systematic prebaiting), and com-

* Monthly Reports from the Kauai Variety Station.

paring this curve with other curves secured by plotting* the rat catch for the corresponding months during the next three years (1939, 1940, 1941) following the start of prebaiting, we have a clear picture which shows a marked reduction in the number of rats caught. These curves are presented in Fig. 1. All commercial cane damage by rats ceased somewhere between the extremes shown in Fig. 1.

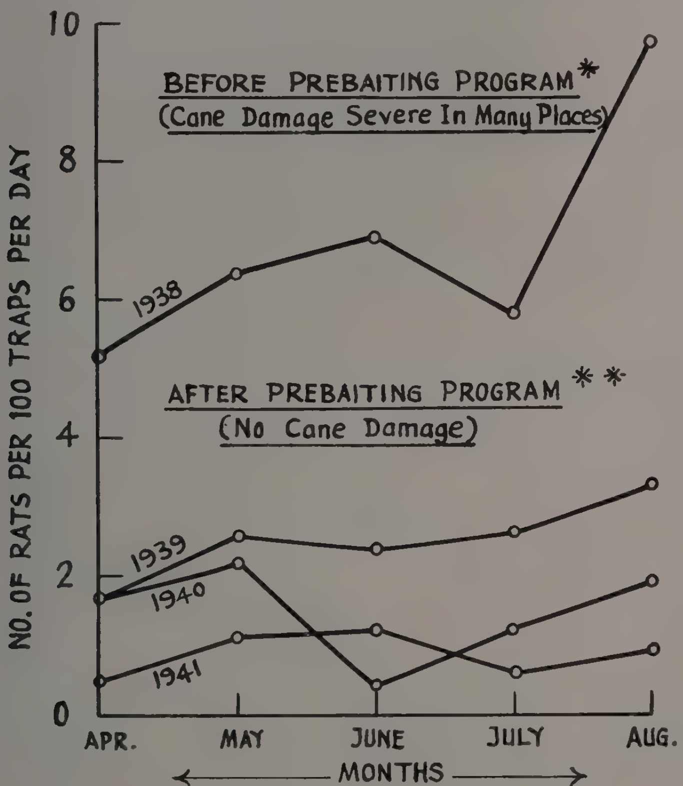

Fig. 1. Graphic presentation of the average number of rats caught per 100 traps per day, comparing the period April to August 1938, just previous to systematic prebaiting, with that of the corresponding months of the years 1939, 1940, 1941 under a systematic prebaiting program. * From Table I. ** From Table III.

The average number of rats caught per 100 traps per day each year (last line in reinfestation prevents any appreciable reduction by the present control methods. An Table III) has been plotted in Fig. 2 and shows a marked reduction in the rat population index from 1938 to 1939 and 1940, followed by only slight fluctuations from 1940 to date. Apparently a low point in the rat population has been reached where almost total absence of rat-eaten cane stalks is evidence that the present schedules of prebaiting and poisoning rounds are giving very satisfactory control.

It is highly probable that any further reduction in the rat population within the cane areas can be attained only at a much higher cost. However, it is feasible to

* From Table III.

move control equipment and personnel into the waste edges from which this continuous reinfestation is emanating and create an effective barrier of rat-free waste country immediately adjacent to the cane. In waste areas where rats are very abundant, Kaeleku Sugar Company, Ltd., is effectively fighting them by maintaining permanent feeding and poisoning stations along "buffer" trails which have been cut in the forest or wasteland 200 to 300 feet from, and running roughly parallel to, the cane field borders.

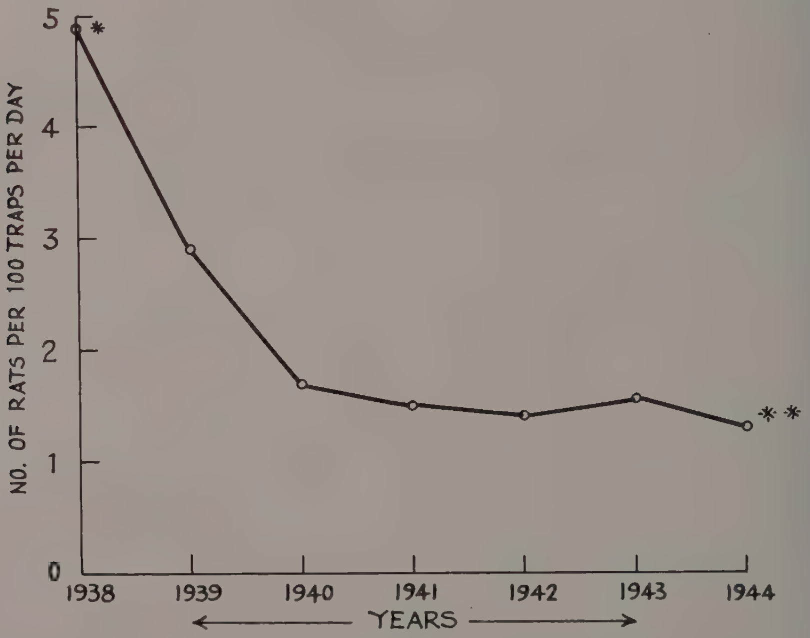

Fig. 2. Average number of rats caught per 100 traps per day under prebaiting control by The Lihue Plantation Company (averages by years for the period from August 27, 1938, to January 25, 1944). * September to December inclusive. ** January only.

TABLE II

RATS CAUGHT PER 100 TRAPS PER DAY WITHIN 18.2 ACRES OF CANE LAND OF THE KAUAI VARIETY STATION (COMPILED FROM DETAILED RECORDS MADE BY MR. STENDER)

Year and month	No. of days 100 traps set	Total rats trapped	No. of rats per 100 traps per day
1938:			
September	29	88	3.0
October	19	73	3.8
November	21	126	6.0
December	29	185	6.4
Totals and avg..	98	472	4.82
1939:			
January	31	106	3.4
February	16	58	3.6
March	31	110	3.6
April	31	54	1.7
May	22	57	2.6
June	31	75	2.4
July	30	78	2.6
August	17	56	3.3
September	31	36	1.2
October	30	87	2.9
November	20	64	3.2
December	30	112	3.7
Totals and avg..	320	893	2.79
1940:			
January	31	120	3.9
February	..	..	...
March	25	15	0.6
April	31	54	1.7
May	15	33	2.2
June	28	10	0.4
July	30	35	1.2
August	21	39	1.9
September	31	41	1.3
October	30	45	1.5
November	21	53	2.5
December	29	52	1.8
Totals and avg..	292	497	1.70
1941:			
January	31	98	3.2
February	31	50	1.6
March	16	16	1.0
April	31	14	0.5
May	30	33	1.1
June	29	36	1.2
July	14	8	0.6
August	31	27	0.9
September	17	18	1.1
October	30	28	0.9
November	31	52	1.7
December	30	95	3.2
Totals and avg..	321	475	1.48
1942:			
January	22	64	2.9
February	31	89	2.9
March	28	81	2.9
April	15	11	0.7
May	21	22	1.0
June	31	26	0.8
July	16	9	0.6
August	31	28	0.9
September	31	17	0.5
October	30	31	1.0
November	31	13	0.4
December	30	57	1.9
Totals and avg..	317	448	1.41
1943:			
January	31	42	1.4
February	31	81	2.6
March	15	16	1.0
April	31	6	0.2
May	30	31	1.0
June	31	39	1.3
July	18	17	0.9
August	30	38	1.3
September	31	83	2.7
October	20	23	1.2
November	28	50	1.8
December	30	79	2.6
Totals and avg..	326	505	1.55
1944:			
January	31	40	1.3

TABLE III

AVERAGE NUMBER OF RATS CAUGHT PER 100 TRAPS PER DAY BY MONTHS, FROM SEPTEMBER 1938 TO JANUARY 1944 INCLUSIVE

Months	Rats per 100 traps (year) 1938	1939	1940	1941	1942	1943	1944	5-year period 1939–1943 Total	Monthly average
January	...	3.4	3.9	3.2	2.9	1.4	(1.3)	14.8	3.0
February	...	3.6	...	1.6	2.9	2.6	...	10.7	2.7
March	...	3.6	0.6	1.0	2.9	1.0	...	9.1	1.8
April	...	1.7	1.7	0.5	0.7	0.2	...	4.8	1.0
May	...	2.6	2.2	1.1	1.0	1.0	...	7.9	1.6
June	...	2.4	0.4	1.2	0.8	1.3	...	6.1	1.2
July	...	2.6	1.2	0.6	0.6	0.9	...	5.9	1.2
August	...	3.3	1.9	0.9	0.9	1.3	...	8.3	1.7
September	3.0	1.2	1.3	1.1	0.5	2.7	...	6.8	1.4
October	3.8	2.9	1.5	0.9	1.0	1.2	...	7.5	1.5
November	6.0	3.2	2.5	1.7	0.4	1.8	...	9.6	1.9
December	6.4	3.7	1.8	3.2	1.9	2.6	...	13.2	2.6
Yearly average	4.82	2.79	1.70	1.48	1.41	1.55	...		

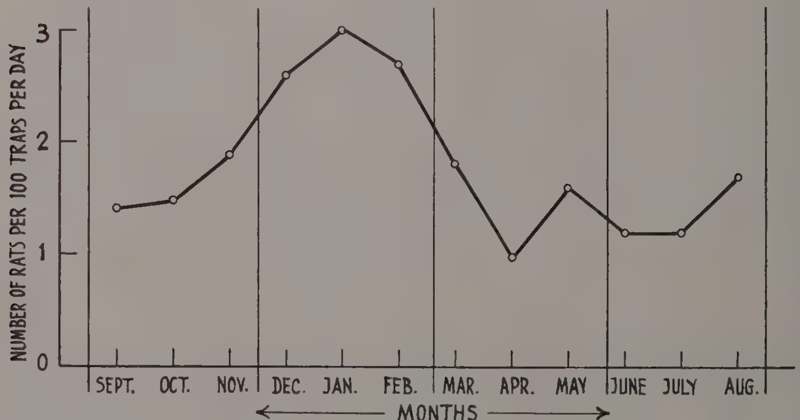

Fig. 3. Average number of rats caught per 100 traps per day under prebaiting control by The Lihue Plantation Company. Five-year average by months—1939–1943 (from Table III, last column).

Seasonal Fluctuation in Rat Population

The seasonal fluctuation of the rat population, in cane fields under the prebaited feeding-station control, is shown in the last column of Table III. This table gives the average number of rats caught per 100 traps per day by months for the five-year period under study. These figures are plotted on the graph in Fig. 3. It is noteworthy that the total range of this seasonal fluctuation in rat population was from a low of one rat per 100 traps per day for April to a high of only three in January. Apparently even three rats per 100 traps per day is very satisfactory, since very little, if any, rat-damaged cane could be found during January.

The period from August or September to January inclusive is a period of increasing rat migration into the cane, which reaches a peak during January of each year and then declines again to a low level occurring from April to August. Thus

these conclusions made from the above data agree with previous observations reported by many fieldmen. Incidently, the period of high pregnancy in rats (April to September inclusive) shown in Spencer's* tabulation coincides rather closely with this period of low migration. Perhaps this fact indicates a tendency of the adult rats to stay in the wasteland where permanent cover is abundant while they are busy at nest building and caring for their young. Then as the young rats grow up and shift for themselves, they migrate to new locations, including cane lands where food may be more abundant, and where if left undisturbed many will establish permanent homes.

A Study of the Change in the Rat Population with Elapsed Time Following a Prebaiting and Poisoning Round

The purpose of this study was to detect any increase in the rat population that was the direct result of the elapsed time between one prebait and poison round and the next. For this purpose Table IV was compiled from the detailed trapping records by weeks between each prebait and poison round for the period from August 27, 1938, to January 25, 1944. The average number of rats caught per 100 traps per day during the total trapping period during each succeeding week after poisoning is shown. The table covers 13 weeks in detail with the 14th, 15th, and 16th week combined because of the small number of records. The periods of poisoning were tabulated first by groups of three months each beginning with: (1) Septem-

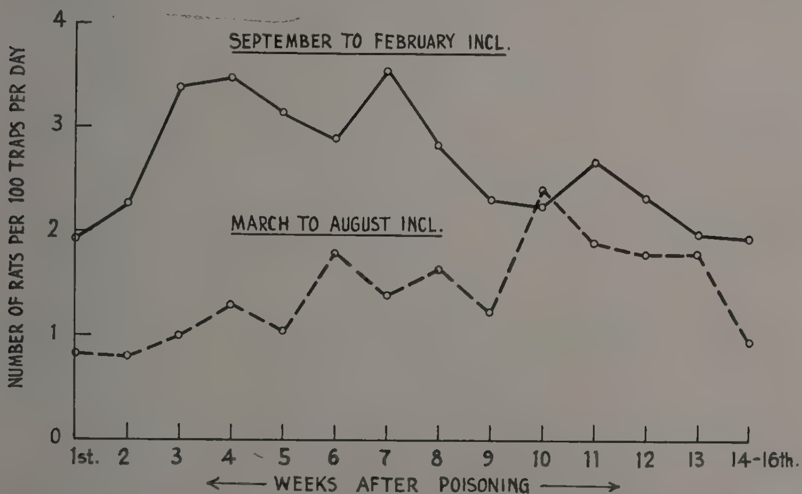

Fig. 4. Average number of rats caught per 100 traps per day during each succeeding week following prebaiting and poisoning campaigns (from Table IV).

The solid line shows the rats caught per 100 traps per day following prebaiting and poisoning done during September to February inclusive.

The broken line shows the rats caught per 100 traps per day following prebaiting and poisoning done during March to August inclusive.

* Garlough, F. E., Spencer, H. J. and Jordan, W., 1937. Hawaiian Rat Project. Semiannual Report (Jan. 1 to June 30, 1937) of the Bureau of Biological Survey. Division of Game Management, Control Methods Research Laboratory, p. 12.

ber, October, and November; (2) December, January, and February; (3) March, April, and May; and (4) June, July, and August. These figures were then combined into six-month periods for comparison. By this arrangement the first two groups covering the period from September to February, which carried the highest averages, were placed together. The graph in Fig. 4 has been prepared from the six-month averages, September to February and March to August inclusive.

It is quite evident that there has been very little change in the rat population within the Variety Station area during the three-month periods between the prebaiting and poisoning rounds. The prebait control work has been so efficient in this

TABLE IV

AVERAGE NUMBER OF RATS TRAPPED PER 100 TRAPS PER DAY FOR EACH WEEK FOLLOWING EACH ROUND OF PREBAITING AND POISONING BETWEEN AUGUST 27, 1938, AND JANUARY 25, 1944

	Months of poisoning						
Weeks following each poisoning round	September October November	December January February	True average September to February	March April May	June July August	True average March to August	True average September to August
1......	1.76	2.64	1.95	0.79	0.86	0.83	1.36
2......	2.04	3.07	2.27	0.74	0.86	0.81	1.46
3......	3.47	3.07	3.38	0.71	1.24	1.00	2.07
4......	3.37	3.79	3.46	1.49	1.10	1.27	2.24
5......	3.43	2.07	3.13	0.89	1.17	1.04	1.98
6......	2.98	2.57	2.89	1.60	1.90	1.77	2.27
7......	3.62	3.29	3.54	1.26	1.52	1.40	2.35
8......	2.48	3.86	2.82	1.83	1.48	1.64	2.14
9......	2.43	1.79	2.27	1.17	1.26	1.22	1.67
10......	2.14	2.36	2.20	2.50	2.31	2.40	2.31
11......	2.88	1.90	2.69	1.68	2.06	1.88	2.26
12......	2.66	0.59	2.31	0.79	2.26	1.76	2.04
13......	2.23	0.87	1.98	0.75	2.64	1.77	1.90
14–15–16......	1.93	....	1.93	0.90	1.00	0.94	1.51
Average	2.70	2.60	2.68	1.27	1.48	1.38	1.98

area that only very low rat populations have been available for this special study. This has prevented us from securing spectacular figures on the amount of reinfestation of rats with elapsed time after a poison round. Under the conditions of this test, it is evident that there is no permanent resident population at the Kauai Variety Station; the rats which have been caught are transients coming from other areas, especially the wasteland in the adjacent gulch.

The present schedule of rounds is considered very satisfactory, since the population has been kept at a low level, with no cane damage reported. The variation in the rat population has been influenced more by the season of the year in which they were caught than by the elapsed time since a poisoning round had been completed. This would explain the slight decline of the September to February curve after seven weeks (see Fig. 4) since the rat population declined and remained low under prebaiting from April to July without any reference to time elapsed after a poison round (see Fig. 3).

Season of Year When Most of the Poisoning Work was Done

It is interesting to note that out of 19 poison rounds covering a period of five years and five months, only two were carried out during December, January, and February, while seven were finished during September, October, and November. During the December to February period the weather is likely to be unfavorable for prebait and poison work. Experience has also shown that extra effort should be put into the field rat-control work beginning with September in order to offset the natural increase in the rat populations which is due to young rats maturing at this time.

Summary and Conclusions

1. A study of the effect of prebaiting and poisoning on the rat population at the Kauai Variety Station was made from August 27, 1938, to January 25, 1944.

2. Before the systematic prebaiting was inaugurated, the field rat population yielded an average catch of *6.8* rats per 100 traps per day for the months of April to August 1938.

3. The corresponding months of the following years (1939–1943 inclusive) under the prebaiting system of control showed that a very satisfactory reduction in the rat population had been maintained as follows:

	Year	Number of rats caught per 100-trap days for the months of April to August
Before prebaiting	1938	6.8
After prebaiting*	1939	2.52
After prebaiting	1940	1.48
After prebaiting	1941	0.86
After prebaiting	1942	0.80
After prebaiting	1943	0.94

* Averages from April to August figures in Table III.

4. The yearly averages (12 months) of the rats caught per 100-trap days since prebaiting was started are as follows:

Year	Rats per 100-trap days
1938 (Sept. to Dec. only)	4.82
1939	2.79
1940	1.70
1941	1.48
1942	1.41
1943	1.55

5. There has been no appreciable rat damage to cane since prebaiting and poisoning by the feeding-station method was started.

6. A study of the seasonal fluctuations of the rat population in the cane field under prebaiting shows that the amount of reinfestation from outside areas begins to rise in October of each year, reaches a peak in December and January, and then declines to April of the year following. From April to July migration to the cane land is at the lowest ebb of the entire year.

7. A study of the change in rat population with elapsed time following a pre-

baiting and poisoning round shows that no significant or damaging increase took place during the interval (averaging 3½ months) between poisoning rounds. The usual seasonal variation in migration to cane land from outside areas was greater than this increase due to the length of time between poisonings.

ACKNOWLEDGEMENT

We wish to express our appreciation for the fine cooperation between the staff of The Lihue Plantation Company, particularly Masato Kawamura, and Mr. Stender and Yuki Inouye of the Kauai Variety Station which has made this study possible.

Susceptibility of Exchangeable Potassium in Hawaiian Soils to Loss by Leaching*

By A. S. Ayres

A study is reported of the effect of intensive leaching on the potassium status of four Hawaiian soils differing widely in available (exchangeable) potassium content. The degrees of potassium saturation of the soils in relation to the losses of potassium, the effect of leaching upon the levels of potassium, and the source of the leached potassium are discussed.

Conditions obtaining in the soils of substantial areas in Hawaii are conducive to loss of potassium by leaching. This loss may be a result of excessive rainfall or of unevenly distributed irrigation water. The susceptibility of soil potassium to leaching under such conditions is largely dependent upon the tenacity with which exchangeable potassium is held by the soil. Little of a quantitative nature is known, however, regarding the abilities of Hawaiian soils to retain exchangeable potassium against the leaching action of water, or of the factors governing such abilities.

Soil-solution potassium, which is small in amount compared with the exchangeable form, is free to move with any movement of the water in which it is dissolved and is therefore highly susceptible to leaching. Exchangeable potassium, on the other hand, is not subject to leaching as such but, under certain conditions, may be readily brought into the soil-solution, or leachable form. This conversion takes place whenever the concentration of potassium in the soil solution is decreased below the level at which the two forms of potassium are in equilibrium. Part of this conversion is normally brought about by carbonic acid resulting from the respiration processes of plants and soil microorganisms. To a greater extent, perhaps, particularly in the absence of vegetation, the release of potassium is accomplished by hydrolysis. The mechanism of this release may be represented by the following equation, where the letter "X" represents the negatively charged colloids comprising the exchange material of the soil and "KX" the exchangeable potassium in combination with this material:

$$KX + H_2O = HX + K^+ + OH^-$$

It will be seen that hydrogen derived from the water replaces potassium in the exchange material thus rendering the potassium free to move with any downward movement of the soil water.

McGeorge (9) determined, in a laboratory study, the losses of potassium which resulted when a number of soils, chiefly from the island of Hawaii, were leached with distilled water. A similar study of two soils from Olaa (Hawaii) was made

* Published by permission of the Director of the Hawaii Agricultural Experiment Station as Technical Paper No. 116. Most of the experimental work was conducted while Dr. L. A. Dean was head of the Department of Chemistry and Soils. The writer is indebted to Dr. Dean for helpful advice and criticism.

recently by Van Brocklin (12). The latter employed distilled water impregnated with sufficient carbon dioxide to simulate rain water. With all of the soils examined by these workers, the leachates contained substantial amounts of potassium even after several successive additions of water had been made to the soils, suggesting that part of the leached potassium was derived from the exchangeable fraction. Magistad (8) reported in a lysimeter study, annual losses of only 15 pounds K_2O per acre resulting from rainfall of 58 inches, and of 28 pounds resulting from 92 inches of rainfall, from two uncropped Oahu soils which had never received fertilizer. In this case it is apparent that losses of exchangeable potassium by leaching were very slight. Fireman and Bodman (5), in California, found that severe leaching with distilled water (1,920 inches) lowered the level of exchangeable potassium in an Aiken clay loam from 1.19 milliequivalents per 100 grams of soil to from 0.26 to 0.54 milliequivalent, depending upon the depth of the soil in the column. The more moderate leaching (65.7 inches) of a Yolo clay loam containing 0.84 milliequivalent of potassium resulted, however, in an almost negligible reduction in the level of potassium. Correspondingly small losses of exchangeable potassium by leaching from calcareous Arizona soils have been reported by McGeorge (10). It is apparent from the foregoing review that widely differing results have been obtained relative to the susceptibility of exchangeable potassium to leaching.

The writer (2), in a study of the abilities of Hawaiian soils to take up potassium from solution, found that with soils containing only moderate levels of exchangeable potassium, sorption occurred even when the concentration of potassium did not exceed a few parts per million K_2O. Soils containing very high levels of exchangeable potassium, however, did not take up potassium until the concentration in the solution was in excess of about 25 p.p.m. It seemed logical to assume that, if a soil is unable to take up potassium from a solution of this concentration, the soil will, if water is substituted for the solution, tend to establish in the water a substantial concentration of potassium. In such soils a portion of the exchangeable potassium would therefore be expected to be very susceptible to leaching.

Experimental

The soils initially selected for the study were a high-potassium sugar cane field soil from Aiea (Oahu), a high-potassium soil from a papaya orchard at Kailua (Oahu), and a virgin Manoa (Oahu) soil which was only moderately supplied with potassium. All of these soils were essentially clay soils. The levels of exchangeable potassium in the soils, together with certain other properties pertinent to the study, are shown in Table I.

Following air drying, a four-pound portion of each soil was placed in a large glass tube, forming a column of soil about one foot in depth. Sufficient distilled water was added to each soil to raise the moisture content to maximum field capacity. Additional water, equivalent to five inches, was then applied to each soil; the resulting leachates were collected and analyzed for potassium. This process was repeated until a total of 520 inches of water had been applied to each soil, except that after the soils had been leached with about 50 inches of water, the five-inch increments of leachate were no longer analyzed individually, several being combined and analyzed as a unit.

After 145 inches of water had passed through each soil, the soil column, divided

into three roughly equal sections, was air dried and analyzed for exchangeable potassium. This was done in order to determine the uniformity of the level of potassium remaining in the column. Following the analysis, the three sections of the soil were returned to their respective positions in the tube and leaching was resumed. At the conclusion of the experiment the columns of soils were, with the exception of the Manoa soil, again sectioned and analyzed.

As the effects of leaching became apparent, it was decided to include in the study a soil representative of the high-rainfall soils of the Hilo coast (Hawaii). Accordingly, leaching was commenced on a sample of soil which had been in the laboratory for some time and which reputedly had been obtained from the Hilo Variety Station of the Experiment Station, H.S.P.A. However, as a result of the determination of certain chemical characteristics of the soil, some doubt was cast upon the origin of the specimen. The sample is, therefore, not accepted as being representative of the area in question and the anonymity is reflected by reference to the soil throughout the paper as soil "A." The soil is very high in exchangeable potassium, as may be seen by reference to Table I. The treatment received by soil "A" was the same as that received by the other soils except that it was leached with only 355 inches of water and was not removed from the tube for analysis until the conclusion of the experiment.

Methods of Analysis

Exchangeable potassium was extracted from the soils with normal ammonium acetate adjusted to pH 6.8. Twenty-five-gram samples were shaken mechanically for an hour with 250 ml. of the solution. After standing overnight the solution was filtered off under suction and an additional 250 ml. allowed to percolate slowly through the soil. Potassium in the leachates was determined by the method of Volk and Truog (13).

Base-exchange capacities were measured by the barium-hydroxide method of

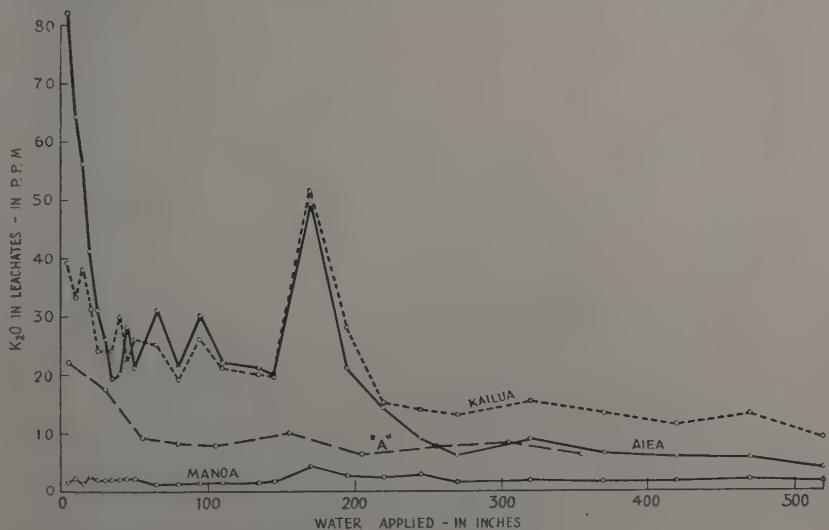

Fig. 1. Potassium in leachates.

Parker (11). The pH values of the ammonium-soils prepared during the procedure ranged from 7.4 to 8.0.

Determinations of pH were made on soil pastes, employing the glass electrode.

Potassium in Leachates

In Fig. 1 the levels of potassium in the leachates are plotted against the amounts of water with which the soils were leached. The level of potassium in the leachate from the moderately supplied Manoa soil did not vary consistently during the early stages of the experiment. Levels of potassium in the leachates from the other three soils, however, were initially high—from approximately 22. to 82. p.p.m. K_2O—but dropped rapidly and irregularly during the early stages of leaching.

The sharp and pronounced increases in the potassium contents of the Aiea and Kailua leachates, and the moderate rise in the Manoa leachate at 145 inches, arose from the air drying of the soils at this point. In the case of soil "A," which was kept moist throughout the experiment, there was no corresponding increase in the concentration of potassium in the leachate.

After the influence of air drying had subsided, the Aiea and Kailua leachates decreased gradually in potassium content until the end of the experiment, at which time the K_2O values were, respectively, 4 and 9 p.p.m. The level of potassium in the leachate from the Manoa soil appears to have been little affected by the leaching; values varied from about 1.5 to 2.0 p.p.m. throughout the experiment, except for a short period immediately following air drying. The leachate from soil "A" dropped only slightly in potassium content following the initial decrease already referred to.

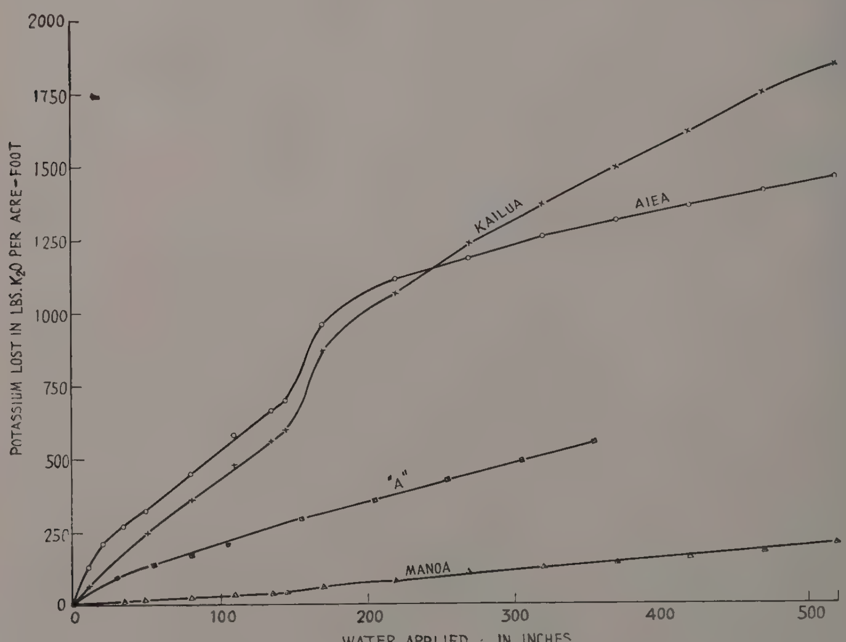

Fig. 2. Losses of potassium by leaching as determined by analysis of leachates.

Losses of Potassium by Leaching

Effect of the Decreasing Level of Exchangeable Potassium:

Curves showing the losses of potassium, based upon analysis of the leachates, are shown in Fig. 2. The unusual shapes of the curves representing the Manoa, Aiea and Kailua soils between 145 and a little over 200 inches resulted from the air drying of the soils.

An inspection of the Aiea and Kailua curves indicates that as leaching progressed the slopes of the curves diminished. This may be seen, in spite of the distortion mentioned, by comparing the slopes prior to drying with the slopes after the influence of the drying had ceased to be manifest. There appears to be only a very slight decrease in the slope of the curve for soil "A." It seems probable that, had this soil been as intensively leached as the others, a more pronounced effect might have been noted. In the case of the Manoa soil no diminution in slope with leaching is observable.

The results appear to indicate that as the amounts of exchangeable potassium in soils abundantly supplied with this nutrient are reduced, the susceptibility of the remaining potassium to loss by leaching is likewise reduced. It seems not unlikely that the same principle may apply to soils at any level of potassium, although at low levels it may be of little or no practical importance, as suggested by the essentially linear nature of the curve for the Manoa soil.

Influence of the Degree of Potassium Saturation:

It is apparent from Fig. 2 that the Manoa soil, which contained the least amount of exchangeable potassium initially (Table I), suffered the least loss of potassium. This observation suggests a relationship between the leachability of potassium and the level of exchangeable potassium in the soil. Upon this basis, however, it would be expected that the Aiea soil, which is second to the Manoa soil in potassium content, would have lost second to the least amount of potassium. Such, however, is not the case. It is thus apparent that, although the susceptibility of potassium to leaching in a *particular soil* may be related to the level of exchangeable potassium in that soil (as seen in the preceding section), the relationship does not appear to hold where different soils are concerned.

Attention may be turned at this point to a consideration of the losses of potassium suffered by the soils in light of the degree or extent to which each soil is saturated with potassium. The "degree of potassium saturation" expresses the quantity of exchangeable potassium in a soil in relation to the base-exchange capacity. It is usually expressed upon a percentage basis. The degrees to which the soils employed in this study were initially saturated with potassium are indicated in Table I.

Reference to Table I and to Fig. 2 will show that the Manoa soil, which lost the least amount of potassium (205 pounds K_2O per acre-foot of soil), possessed also the lowest degree of potassium saturation, or 2.3 per cent. Soil "A," which lost much more potassium than the Manoa soil, possessed a degree of potassium saturation of 5.0 per cent, or a little more than double that of the Manoa soil. Similarly, the Aiea soil, with a degree of saturation of 7.3 per cent, sustained a greater loss of potassium than soil "A," and the Kailua soil, with the highest degree of saturation (8.4 per cent), suffered the greatest loss of potassium, or 1,845 pounds K_2O.

TABLE I

EXCHANGEABLE POTASSIUM CONTENTS OF THE SOILS AT VARIOUS STAGES OF LEACHING, AND INITIAL AND FINAL pH VALUES

Description	Rainfall	Section of soil column	Base-exchange capacity	Initial degree of potassium saturation	pH Initial	pH Final	Exchangeable Potassium: Initially	Remaining after 145 inches		Remaining after 355 inches		Remaining after 520 inches	
	inches		*m.e./100 gm.*	*per cent*			*m.e./100 gm.*	*m.e./100 gm.*	*per cent*	*m.e./100 gm.*	*per cent*	*m.e./100 gm.*	*per cent*
Manoa, residual	165	top	24.0	2.3	5.2	...	.56	.49	87.5	....	....	....	....
virgin soil		middle	24.0	2.3	5.2	...	.56	.55	98.2	....	....	....	....
		bottom	24.0	2.3	5.2	...	.56	.56	100.0	....	....	....	....
		mean	....	...	...	5.2[2]	....	....	95.2[1]	....	....	.45[2]	80.3[2]
Aiea, residual	45	top	17.9	7.3	5.7	5.2	1.30	.53	40.8	....	....	.31	23.8
sugar cane		middle	17.9	7.3	5.7	5.4	1.30	.76	58.5	....	....	.39	30.0
field soil		bottom	17.9	7.3	5.7	5.5	1.30	.82	63.1	....	....	.45	34.6
		mean[1]	....	...	...	...	....	....	54.1	....	....	....	29.5
Kailua, alluvial	50	top	28.9	8.4	6.2	5.6	2.43	1.58	65.0	....	....	.69	28.4
papaya orchard		middle	28.9	8.4	6.2	5.7	2.43	2.01	82.7	....	....	.91	37.4
soil—formerly		bottom	28.9	8.4	6.2	5.8	2.43	2.35	96.7	....	....	1.15	47.3
in pasture		mean[1]	....	...	...	...	....	....	81.5	....	....	....	37.7
"A"	..	top	39.1	5.0	6.5	6.1	1.95	....	....	1.35	69.2	....	....
		middle	39.1	5.0	6.5	6.1	1.95	....	....	1.60	82.0	....	....
		bottom	39.1	5.0	6.5	6.1	1.95	....	....	1.62	83.1	....	....
		mean[1]	....	...	...	...	....	....	....	....	78.1	....	....

[1] These values only approximate the true averages since the weights of the sections were not identical.
[2] The Manoa soil was not sectioned at the conclusion of the experiment.

The degrees of potassium saturation in the soils studied thus appear to account nicely for the losses of potassium sustained by the soils at the conclusion of the experiment. But they fail to explain why potassium was lost more rapidly from the Aiea soil than from the Kailua soil during the first half of the experiment. It may be pointed out, however, that the losses during this period did not differ greatly for the two soils, nor was the initial difference in the degrees of potassium saturation very great. Moreover, it will be noted that with the widening in the gap between the degrees of saturation, as a result of the more rapid loss of potassium from the Aiea soil during the first half of the experiment, a point was reached at which the rate of loss from the Aiea soil was exceeded by that from the Kailua soil.

It is not supposed that the degree of potassium saturation is the entire answer to the susceptibility of potassium to leaching. It seems evident, however, from a consideration of the present results, that the degree of potassium saturation offers a more satisfactory indication of the susceptibility of potassium to leaching than does the mere level of exchangeable potassium in the soil.

It may prove reassuring to recall that in a recent study of high-rainfall soils by the writer (3), high base-exchange capacities were generally found to prevail. Since the levels of exchangeable potassium in these soils were only moderate, the degrees of potassium saturation were on the whole very low—in many instances even lower than in the Manoa soil employed in the present study. This suggests that losses of potassium by leaching in regions of high rainfall may not be so great as might be anticipated.

Influence of Leaching on the pH and on the Levels of Exchangeable Potassium

pH Values:

The replacement of exchangeable bases by hydrogen in soils results in increased acidity. Since such replacement occurs when soils are leached with water it would be anticipated that some evidence of increased acidity should have resulted from the determination of the pH values of the soils before and after leaching. Referring to Table I, it will be observed that marked increases in acidity resulted from leaching in three of the four soils. The Manoa soil, which was the most acid initially (pH 5.2), and which experienced the least loss of potassium, was not made measureably more acid by leaching.

Levels of Exchangeable Potassium:

The effect of leaching upon the levels of exchangeable potassium in the soils is brought to light in Table I. Considering first the Manoa soil, it will be seen that leaching with 145 inches of water reduced the level of exchangeable potassium, for the soil as a whole, to 95.2 per cent of the original value. The passage of additional water through the soil further reduced the level of potassium so that at the end of the experiment only 80.3 per cent of the original amount remained. In the case of the Aiea soil the reduction was much more severe: at 145 inches the average level of potassium had dropped to 54.1 per cent of the amount initially present and, by the end of the experiment, to 29.5 per cent. The amounts of exchangeable potassium remaining in the Kailua and "A" soils upon completion of leaching were, respectively, 37.7 and 78.1 per cent of the original levels. The reductions in levels

of exchangeable potassium in the Aiea and Kailua soils are comparable with those brought about by Fireman and Bodman (5) on Aiken clay loam.

It is evident from inspection of the levels of exchangeable potassium in the several sections of the soil columns that depletion of the soil was far from uniform. Levels of potassium following leaching are seen, in every instance, to increase with increasing depth in the column. Similar results were obtained in the study referred to just above. The simplest explanation of this differential loss of potassium appears to be that the water, as it moves downward through the soil, increases in potassium content and as a result its effectiveness as a leaching agent continually decreases. In view of the marked resistance of Hawaiian soils to dispersion, it seems unlikely that colloidal migration could account for the observed differential.

Source of the Leached Potassium

If all of the potassium leached out of the soils was derived from the soil-solution and exchangeable forms, then it should be possible to account for this potassium on the basis of the quantities of exchangeable potassium* present in the soils, before and after leaching. The quantities of potassium lost from the soils, calculated upon the two bases, and taking into account the soil removed from the tubes for analysis during the course of the experiment, are shown in Table II in terms of pounds of K_2O per acre-foot of soil.

TABLE II

LOSSES OF POTASSIUM BY THE SOILS AS A RESULT OF LEACHING

Soil	Initial level of exch. potassium *lbs.* K_2O*/acre-ft.*	Final level of exch. potassium[3] *lbs.* K_2O*/acre-ft.*	Loss in exch. potassium by difference *lbs.* K_2O*/acre-ft.*	Loss in potassium by analysis of leachates *lbs.* K_2O*/acre-ft.*	Loss in potassium by analysis of leachates minus loss by difference *lbs.* K_2O*/acre-ft.*
Manoa[1]	665	535	130	205	75
Aiea[1]	1,535	445	1,090	1,460	370
Kailua[1]	2,865	1,075	1,790	1,845	55
"A"[2]	2,300	1,795	505	550	45

[1] Leached with 520 inches of water.
[2] Leached with 355 inches of water.
[3] Weighted mean for the entire soil column.

In the case of every soil the amount of potassium lost, as determined by direct measurement, exceeded that lost, as measured by difference. With the Manoa, Kailua, and "A" soils, these differences were small—from 45 to 75 pounds K_2O—and may be without significance. There seems little question, however, that in the Aiea soil some form of potassium other than the soil-solution and exchangeable forms contributed to the observed leaching loss.

It may be contended that the method employed in the determination of potassium did not remove all of the exchangeable potassium from the soils. Although the possibility cannot be denied, the method employed (see Methods of Analysis) provides for an unusually thorough treatment. Moreover, had the potassium unaccounted for been the result of incomplete extraction in the determination of exchangeable potassium, differences of similar magnitude might have been expected with the other soils studied.

* The laboratory determination of exchangeable potassium includes the soil-solution potassium.

During the last ten years it has been shown that in some mainland soils and under certain conditions considerable amounts of non-exchangeable potassium may be converted to exchangeable and soil-solution forms over a relatively short period of time. Similar conclusions have been drawn by Abel and Magistad (1) and by Borden (4) as a result of their efforts to evaluate available potassium in Hawaiian soils. In view of the results of these workers, it seems not unreasonable to suppose that that part of the potassium lost from the Aiea soil, which could not be accounted for on the basis of the diminution in exchangeable potassium, was converted from a non-exchangeable to the leachable form during the course of the experiment. The observation is of interest also in view of the studies of Hough and his associates (6, 7) which revealed the presence of considerable amounts of potassium in the colloidal fractions of some Hawaiian soils.

Summary

The results of a laboratory study of the effects of leaching upon the potassium status of four Hawaiian soils may be summarized as follows:

1. Air drying was found to increase the susceptibility of potassium to leaching.
2. In soils at high initial levels of exchangeable potassium, the susceptibility of potassium to leaching appears to diminish with decreasing level of potassium in the soil.
3. The degree of potassium saturation of a soil appears to be a more reliable guide to the susceptibility of potassium to leaching than does the level of exchangeable potassium. Losses of potassium were found to be greater, the higher the initial degrees of potassium saturation.
4. The quantities of potassium lost from the soils ranged from about 200 to 1,850 pounds K_2O per acre-foot of soil.
5. The acidity of the soils was generally increased as a result of leaching.
6. Levels of exchangeable potassium were reduced by leaching to from about 30 to 80 per cent of the original values.
7. A substantial amount of potassium apparently from a non-exchangeable source was leached from one of the soils studied.

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A Survey of Insect Pests of New Caledonia

By Francis X. Williams

Many insect pests of plant crops are here considered. A large number of these pests do not occur in Hawaii. A short account of the island of New Caledonia and its natural history is included.

In May 1940 the Experiment Station of the Hawaiian Sugar Planters' Association sent the writer to New Caledonia to collect and study the insect pests of that large island. Thus in securing a better knowledge of these pests we would be more fully prepared to prevent their entrance into this Territory or to deal immediately with any such that did perchance succeed in establishing themselves here. So rapid and extensive is the development of modern transportation, particularly by the airplane, that preventive measures not always having kept pace, the danger of accidental introduction of insects and other pests seems every day to become more real.

Sailing from Honolulu on May 27 and arriving at Noumea, capital of New Caledonia, on July 3 *via* a rather circuitous route, I spent over four months in entomological work in various parts of the island, and departed from it *via* Pan American Airways on November 12. The data secured are perhaps representative though quite incomplete, for to make a thorough survey of the insect pests of so large and rugged an island, the biota of which is sometimes affected by conditions of drought or flood, would be a matter of years rather than of months.

During my entire stay in New Caledonia I was the recipient of much kindness and assistance. I am much indebted to Professor Jean Verges, Director of Agriculture, who opened the way for my entomological investigations in the truck gardens of New Caledonia and who assisted me in other ways. Lee Johnson of Noumea kindly placed his vegetable and ornamental garden at my disposal for studying the insects associated with it. Thanks are due to the Marist fathers at their mission at St. Louis, a few miles from Noumea and where some native gardens were situated. Through the hospitality of Mr. and Mrs. L. Want at their ranch at Oua Tom on the west coast, I was able to observe pests of cotton and coffee. Robert Virot, an able botanist, helped in the identification of various plants, while the several field trips with him proved to be of great interest. I received much assistance in travel, both by sea and by land: to the Isle of Pines (Kunie) and way points (courtesy of Tibbie Hagen); to a lumber camp near Nepoui, just beyond Poya and about 150 miles up the west coast; to Hienghene some 170 miles up the east coast; and to other points. Albert Roger proved indispensable in his knowledge of people and places, in making arrangements relative to our trips, and by his reassuring operation of the automobile. Mrs. Williams, who accompanied me, took all the photographs in New Caledonia and otherwise helped me in my work. The photographs of mounted specimens were made by W. Twigg-Smith of this Experiment Station.

Past work in entomology in the Pacific Islands has been of great aid to me in the identification of insects, their economic status, distribution, etc. This is particularly true of the careful investigations in Guam and Samoa of O. H. Swezey, consulting entomologist of this Experiment Station. Mr. Swezey has personally helped me determine a number of insect species. D. T. Fullaway, entomologist of the Territorial Board of Agriculture and Forestry, has determined the aphids or plant lice, many of the scale insects, and nearly all the parasitic wasps in the New Caledonian collection. F. A. Bianchi, assistant entomologist of this Experiment Station, has studied the Thysanoptera or thrips and will soon publish on this important group of insects. C. E. Pemberton, executive entomologist at this Experiment Station, has brought together a list of some of the most important insect pests of New Caledonia, and this list has been found very useful. Finally a catalogue of insects known to occur in New Caledonia, kindly furnished the Experiment Station by E. C. Zimmerman, entomologist of the Bernice P. Bishop Museum, Honolulu, has helped a great deal.

Unfortunately I have not seen—except in review—Dr. Risbec's fine papers nor the excellent publications of others on New Caledonian insect pests.

The island of New Caledonia (Fig. 1) was discovered by Captain James Cook in 1774, and is a dependency of France. It has a northwest-southeast trend and

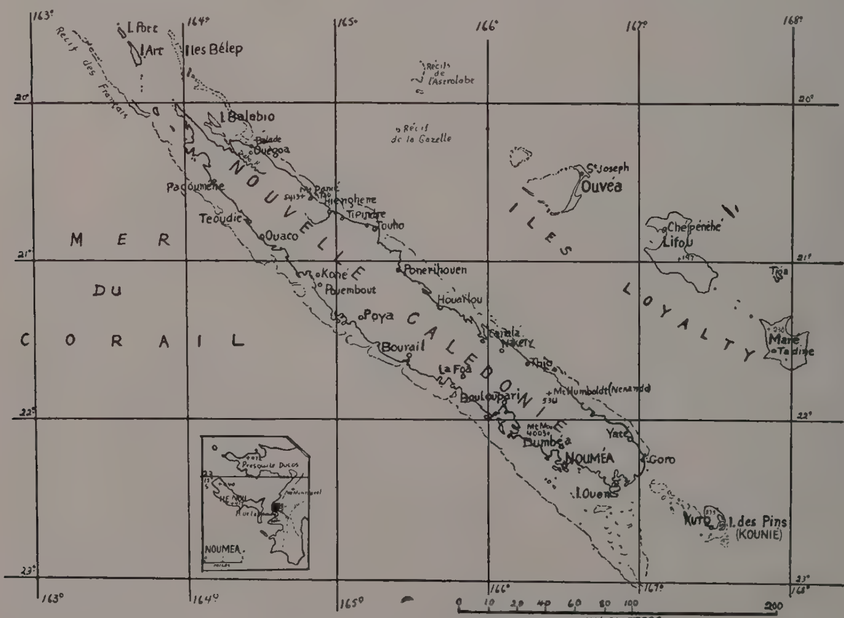


Fig. 1. Map of New Caledonia.

lies between latitudes 20° 1′ and 22° and 26′ south and longitudes 164° and 167° 40′ east. It is about 750 nautical miles northeastward of Brisbane, Australia, somewhat less that distance southwestward of Fiji and about 3,300 miles southwestward of Honolulu, Hawaii. It is approximately 248 miles long with an average breadth of 25-30 miles and has an area of 6,274 square miles, or more than half again as

large as the island of Hawaii. Less than 30 miles beyond its southern extremity is the Isle of Pines (Kunie), area 58 square miles, while 50 miles or more off the east coast are the small Loyalty Islands. All of these islands and some others are under the jurisdiction of New Caledonia. Noumea, population about 12,000, is near the extremity of a small peninsula on the west coast near the southern end of the island. North and east of the main island of New Caledonia are the New Hebrides, the nearest island of which is over 200 miles distant.

New Caledonia is enclosed by coral reefs. The island is ruggedly mountainous, the highest points being Mount Panie in the north and Mount Humboldt in the south. Both are approximately 5,400 feet high. Some 20 miles northwest of Noumea is the square-topped Mount Mou, elevation about 4,000 feet, a familiar landmark from the city and its environs and somewhat recalling our Mount Kaala of Oahu in its broad, apparently level summit. Recent figures (prior to 1940) give the population of New Caledonia as about 53,000, of which the natives—chiefly Melanesians—constitute somewhat more than half, the whites nearly a third, with Japanese, indentured Javanese and Tonkinese making up the remainder.

New Caledonia is a very ancient land mass; there is much palaeozoic rock and no volcanic activity. In the north there is a fine gneiss mountain chain, which includes Mount Panie. Near Hienghene and standing out to sea from a scenic craggy coast are the "Tours de Notre Dame de Paris", a pair of towering rocks arising from a common base, of crystalline limestone. But the most familiar country consists of serpentine rock. To quote R. H. Compton (*Geographical Journal*, 90: 81-106, 1917, 12 photos, on page 85) "Owing to the great quantity of iron contained in the rocks the whole of the serpentine country has a very characteristic red ochre colour, . . ." In fact much of the surface rock is very heavy and strikes with a distinct metallic ring. But the lack of good coal has made this iron (haematite) comparatively useless. New Caledonia, however, is rich in workable minerals, with nickel, chrome, and cobalt outstanding. Nickel is shallowly mined by terracing the hill tops or cutting into the hill sides. This mineralized area constitutes a kind of plant zone, the vegetation being rather stunted on the impoverished soil.

The rainfall is fairly abundant over the island: "The average rainfall from 1908 to 1912 was 1845 mm (73 inches) per annum, distributed over 142 rainy days." (Compton, ibid:89–90.) It is not evenly distributed and some of the lower country is rather arid. The rainy season is from December to March—more or less. Occasionally there are cyclones, and the east-southeast trade winds are often vigorous. The climate is rather mildly tropical but it becomes slightly cooler at sea level than in the Hawaiian Islands. During almost our entire stay in New Caledonia, from July to November, the weather was almost ideal although not the best time of the year for insects.

The east coast is more rugged and generally wetter, the mountains sloping steeply towards the sea, their streams often debouching from narrow valleys. Roads are fewer and one usually crosses the estuaries by ferry barge. The west coast has some plains and is fringed here and there by mangrove swamps. Particularly on the west coast and frequently extending up the mountains to an altitude of 3,000 feet or more are large areas of open forest consisting almost entirely of "niaouli" (*Melaleuca leucadendron* Linn., variety *viridiflora* Gaertn.) of the

Myrtaceae or Eucalyptus family (Fig. 2). It is practically the same as the Australian *Melaleuca leucadendron* which has been introduced into Hawaii where it is commonly known as the paper bark. This picturesque if frequently rather scrubby and distorted tree with its shaggy, pale-brown bark and narrow dull-green leaves gives the New Caledonian landscape a rather hazy appearance that is far from tropical. The niaouli is a very hardy tree, withstanding wind and drought as well as considerable salt water. Grass will grow beneath its dubious shade so as to permit pasturage. Its flowers appearing seasonally in great profusion are said to be the

Fig. 2. "Niaouli" forest (*Melaleuca leucadendron* var. *viridiflora*).

mainstay of the honeybee. The medicinal "essence de niaouli" is made from the leaves, the layered papery bark is extensively used in the "bush" for thatching, the wood makes good charcoal, or when properly dried, excellent firewood, and suitably curved trunks or large limbs are sometimes employed in boat building. It is also used a great deal for fence posts.

Several species of wattle (*Acacia*) are found from sea level to well up in the mountains. The "haut forêt" or high forest is composed largely of endemic trees. Such forests are to be seen in pockets in the valleys and on the higher mountains where there is sufficient moisture. Here tree ferns may attain a height of 50 feet or more. *Blechnum* ferns and others add greatly to the beauty of forest streams. Palms are not conspicuous. These forests in many places have been badly cut

and their future is not reassuring. Such fine trees as the several species of kauri pine (*Agathis*), that occur in little groups or colonies and perhaps the most stately of New Caledonia's forest giants, have already been greatly reduced in numbers, in part as export for matchwood. The less valuable but picturesque "pin colonnaire" (*Araucaria Cookii* R. Br. [=*A. columnaris* Hook.]) furnishes a cheaper type of lumber for many uses. One or more species of *Araucaria* often form part of the skyline of the mountains. To the south, *Araucaria Cookii* is frequently the outstanding tree of coral islets.

As in the Hawaiian Islands of old there was an extensive trade in sandalwood in New Caledonia.

As one enters the harbor of Noumea, the brown hills overlooking the city present a rather barren picture. In addition to the usually dry grass, there are introduced weeds and shrubs now common to many tropical countries. The ordinary bush lantana (*Lantana camara* Linn.) helps form thickets on the hillsides, but this plant or a variety of it with particularly attractive blossoms is often grown in gardens. The dainty little *Lantana sellowiana* Link and Otto seeds itself freely and forms patches of purple over the landscape. A tough verbenaceous weed (*Stachytarpheta*) is common, and these several plants together with the thorny *Acacia farnesiana* Willd., our "klu bush," often make walking along the overgrown trails difficult. The Christmas berry tree (*Schinus terebinthifolius* Raddi) and the lemon guava (*Psidium guajava* Linn.) flourish in New Caledonia as in Hawaii. One or more species of *Sida* are common city weeds. At least two kinds of prickly pear cactus are found about Noumea; the abundant one has the flattened branches not as fleshy as usual and the second species, of which I saw but few individuals, is a sturdier plant with larger thorns and which I was told had been very greatly reduced in numbers by the larva of the Argentine *Cactoblastis* moth that has so efficiently dealt with the prickly pear in Australia, from which country it was imported into New Caledonia.

Other plants more natural to the country may be seen in the hills back of Noumea. Waist-high thickets of dark green are formed by a dwarf ironwood (*Casuarina collina* Poisson?), while shrubs that closely resemble our *Dodonaea* and *Wikstroemia* are scattered on the slopes. In the gulches are remnants of forests of low trees.

While New Caledonia is rich in species of insects, vertebrate animals are poorly represented. Best known of the wild animals is an Indian stag deer sufficiently abundant to be a pest, so that many estates, particularly those engaged in raising cattle (the meat-canning industry being large) maintain a deer hunter. There is, consequently, quite an export trade in deer hides. Species of rat and pig occur and are sometimes considered as dating back from prehistoric times. Among the bats of New Caledonia are three species of flying foxes or large fruit-eating bats. Locally known as "roussetes," they are often prized as food and are said to descend periodically from their mountain fastnesses to feed upon the flowers of the niaouli tree. Town birds are represented by the mynah—not as assertive it would seem as in Hawaii; the house sparrow; fig-loving white-eyes; a honeysucker known as the longbec, a fine singer often seen probing hibiscus flowers; and a few other birds. Along the roads near the sea one often sees a partly green- and blue-marked little kingfisher (*Halcyon*) perched on the electric power wires. A crow and several hawks are common. Owl pellets—regurgitated wads of indigestible animal material—collected in the hills behind Noumea indicate that the food of this bird consists to a great extent of small

rodents, large grasshoppers and crickets. No remains of birds were found in these pellets. One often finds bleached specimens of a large noctuid moth, perhaps of the genus *Anua* and whose caterpillar feeds upon the leaves of the niaouli, skewered on the strong thorns of the shrubby *Acacia farnesiana* (Fig. 3). This is probably the work of shrikes or butcher birds, which are numbered among the avifauna of the island. In the forests are the "kagu" (*Rhinochetus jubatus* Verreaux and Des Murs), a ground-inhabiting heron-like bird; the "notu" (*Phaenorhina goliath* Gray), which is a very large pigeon; a crow; some parakeets; and other interesting forms. There are apparently no land snakes but plenty of skink and gecko lizards; one species of gecko (*Rhacodactylus leachianus* [Cuv.]) dwelling on trees and in the fissures of

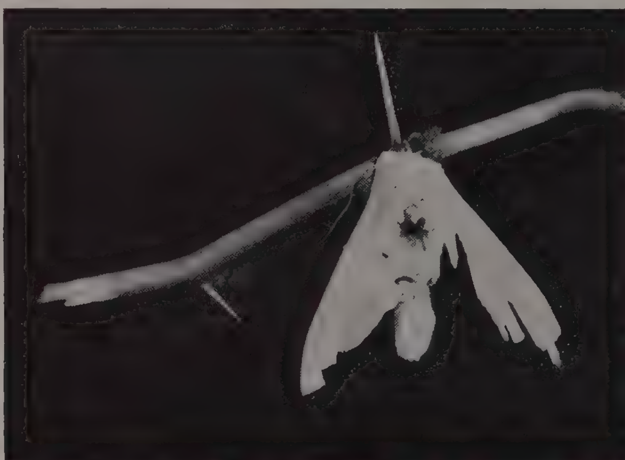


Fig. 3. Moth skewered on thorn of *Acacia farnesiana.*

rocks attains a length of more than a foot and is much feared by the natives. Large terrestrial snails (*Placostylus*), some with shells five inches long, occur on the ground near the shore or in the depth of the forest. They appear harmless to vegetation. These snails or "escargots" are often served in restaurants as delicacies, although not universally acclaimed as such. The common European snail (*Helix aspersa* Müll.) (Fig. 4) is an escape in gardens where it is a great pest. The mother of pearl and the troca shells from the sea have been much used in the manufacture of buttons.

In normal times coffee and copra (the dried meat of the coconut) are the most important agricultural exports. An attempt has been made to grow cotton on a commercial scale, but because of pests and perhaps for other reasons, it did not succeed. Rice was formerly planted over considerable areas, and likewise sugar cane; of the former I saw a tiny planting, and the latter is to be seen in many of the small native gardens but seldom elsewhere, and nowhere in commercial quantity. There are many home gardens and also a good deal of truck farming. The natives have added the usual vegetables to the staple taro, banana and sugar cane. Hillsides of abandoned terraces bear mute testimony to a more flourishing aboriginal agriculture. A very thick-skinned gouty-looking lemon grows abundantly along certain fields and roadsides, while the little mandarin orange is common in cultivation but also grows in the wild state. Mangoes and avocado pears are plentiful in season, but we saw only

one or two breadfruit trees during our entire four-month stay in the island. Occasional hurricanes may severely damage crops, thus creating a scarcity of such fruits as bananas and papayas.

During my stay in New Caledonia I saw no large outbreaks of insect pests save perhaps of day mosquitoes, and it is presumed that these insects are locally numerous

Fig. 4. Common European snail *Helix aspersa.* About natural size.

at least periodically. Certain harmful insects were so sparingly taken or found on plants of no economic value, as not to be recognized at the time as pests. However, the presence of the immature stages of some injurious insects up to the time of my departure suggested that pests might later become more abundant.

The economic insects are herewith listed according to host. The list is based on my own collecting and upon the work of others as recorded in literature. Needless to say many more insect pests remain to be recorded from New Caledonia. Species not taken by me are marked with an asterisk (*) ; those not known to occur in Hawaii are marked with a degree sign (°).

Banana

Nacoleia octasema (Meyrick)°: The banana scab moth, the caterpillar of which is a serious pest, feeds among the young bananas of the bunch. The bananas develop an unsightly scab and become more or less unsalable. The mature caterpillar is reddish with numerous small dark plates (Fig. 5). It is apparently widespread on bananas in New Caledonia and extends as far east in the Pacific as Samoa where Mr. Swezey has studied it (*The Hawaiian Planters' Record,* 45: p. 30, 1941). Mr. Swezey states: "Damage is checked by dusting with sulphur at the proper time."

Cosmopolites sordidus (Germar)°: The banana weevil is blackish and about the size of the sugar cane weevil borer. It is found in the tropics of both hemispheres, occurring on many Pacific Islands including Guam and Samoa. The larva feeds in the base of the banana plant and also destroys the shoots. A single adult weevil was found on an old banana plant at the base of Mount Mou, New Caledonia. It is a long-established pest on this island.

Citrus

Mandarin oranges of good quality are an important fruit in New Caledonia. They are common in gardens and also grow wild. In many places lemon trees with

Fig. 5. Banana scab moth caterpillar (*Nacoleia octosema*). Much enlarged.

thick gouty-looking fruit grow by the wayside. Grapefruits were seen in cultivation near Mount Mou.

Aleuroplatus (*Orchanus*) *samoanus* Laing°: This aleurodid or whitefly is sometimes common on the leaves. Aleurodidae are related to aphids and scale insects.

Icerya purchasi Maskell: The cottony cushion scale, one specimen of which was taken on the twig of a tree. Isle of Pines.

Pulvinaria sp.: On citrus. Noumea.

Pseudococcus citri (Risso): Noumea.

Pseudococcus filamentosus (Ckll.): On citrus twig. Noumea.

Ceroplastes rubens Maskell: A wax scale common on the leaves of citrus, *Melaleuca* and many other plants.

Lepidosaphes becki (Newman): On the leaves of orange trees and on mandarin oranges in store. Noumea.

Pseudaonidia trilobatiformis Green°: On citrus leaf.

Myctis profana (Fabr.)°: Only two specimens of this bug, which is just under an inch long, were taken. To quote Froggatt (Australian Insects, p. 332, 1907): "It . . . has been found infesting the citrus orchards where it punctures the young shoots and causes them to die back." (Australia.)

Dacus psidii Froggatt°: The guava fruitfly attacks many kinds of fruits but favors guavas. C. Jacques has studied this pest in New Caledonia (*La mouche des fruits de la Nouvelle-Calédonie,* Rev. Agri. Nouv. Caledonie, 1938: 3133–3138, 6 figs. Noumea, August 1938).

Papilio amyntor Bdv.°: A fine large swallowtail butterfly (Fig. 6), the caterpillar of which feeds on the leaves of *Citrus* sp. The butterfly is common in the city of Noumea.

Orthreis fullonia (Clerck)°*: This fine, large, fruit-piercing noctuid moth has the proboscis modified for piercing. It attacks many kinds of fruits. The showy caterpillar feeds on the leaves of *Erythrina.*

Citrus leaf miner°: The caterpillar of a very small moth mines the leaves, beginning the mine at the margin and terminating it as a more or less inflated blotch. The moth was not reared. Dumbea.

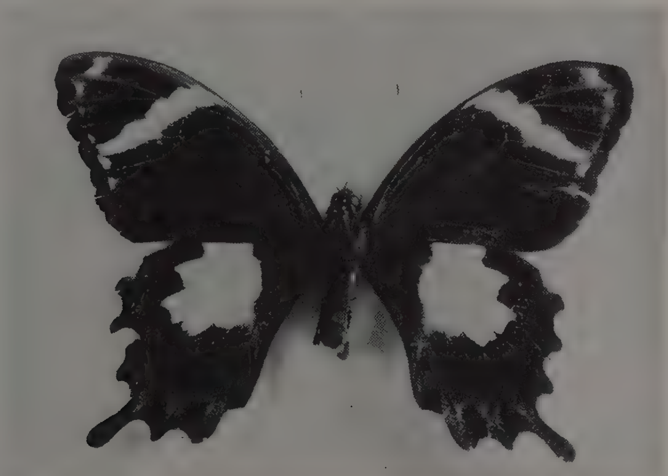


Fig. 6. Citrus swallowtail (*Papilio amyntor*). Slightly reduced.

Coconut

As determined in recent years, copra, the dried meat of the nut is, next to coffee, highest in export value among the agricultural products. The coconut palm is abundant in the lowlands of New Caledonia, and on the east coast there were considerable plantings of it. Many pests were attached to it as follows:

Aspidiotus destructor Sign.°*: The coconut palm scale is widely distributed in the Pacific. It was reported as injurious on coconut palms in New Caledonia, but was held in some control by parasites, the most important of which was an aphelinid wasp (Risbec, 1936).

Aspidiotus hederae Vall.: Reported by F. Laing in *The Coccidae of New Caledonia,* Ann. and Mag. Nat. Hist. (10) XI, 675–678, 1933.

Chrysomphalus aonidum (Linn.): This is the Florida red scale. It rather seriously damages the young fronds, producing yellowish spots which enlarge and cause a drying of the leaf tissue. La Foa, September, on young coconut palms; Noumea, September, on leaves of *Bauhinia* tree (Leguminosae).

Ripersia palmarum Ehrhorn: This mealybug was found in the unopened frond of a coconut palm at St. Louis in August.

Aleurodicus destructor Mackie°*: Neither this nor the following aleurodid is said to be very destructive to the coconut palm.

Aleurocanthus sp.°*:

Phaciocephalus sp.°: This is a slender-winged derbid leafhopper with straw-yellow wings marked by a pink and brown stripe. This insect seemed not to be injurious.

Only adults were found and these were not very common. The young do not feed upon the fronds. La Foa, October; Noumea, August.

Graeffea crouani (Le Guillou)°*: This large stick insect is also found in Fiji, Samoa and Tonga. It eats abundantly of the coconut foliage. It is sometimes recorded under the name of *Graeffea cocophaga* Newp.

Hemarchus pythonus (Westw.) °*: This is another large stick insect that damages the coconut palm. Immature walking-stick insects were occasionally seen in a forest clearing where they damage foliage.

Grasshoppers: Immense "sauterelles" or grasshoppers that stridulate were reported to me as damaging the fronds. These may have been a species of long-horned grasshoppers, the young of which were often found resting on sugar cane.

Tirathaba rufivena Wlk.°*: This is a pyralid moth the larva of which eats the young nuts and male flowers of the coconut. This insect ranges from Ceylon through the Solomons to New Caledonia.

Agonoxena sp.°*: This is a small tineid moth, the larva of which eats the leaflets under the cover of the silk cases.

Fig. 7. Coconut palm moth (*Tonica* sp.?). Expanse 26 mm.

Fig. 8. Coconut palm larva. Length 15 mm.

Tonica sp.? (Oecophoridae)°: This small moth (Fig. 7) is evidently widely distributed in New Caledonia. The caterpillar (Fig. 8) does some damage to the fronds, its work somewhat resembling that of the coconut leafroller, *Omiodes blackburni* (Butl.), in Hawaii. It fastens together very strongly with silk the two sides of a leaflet or one leaflet and the adjoining one. In the retreat thus formed it eats here and there part way through the leaflet. The dull-colored caterpillar is a little less than an inch long; there is a dark band across the forehead and some dark

Fig. 9. Coconut palm pupa. Length 11.5 mm.

color about the mouth. Rather long hairs arise from little brownish tubercles. When about to transform it spins a silken mat upon the upper surface of a leaf or other object and fastening the end of the abdomen in this mat, sheds its skin to become a stout pupa (Fig. 9). This pupa is sharply conical at the head, and is gen-

erally beset with little tubercles curiously tufted with short finely branched processes. The flat sole-like tail end is planted on the silk mat and the pupa literally leans backwards. The ensuing moth expands an inch or more and has blunt pale-brown forewings flecked with black, and plain brownish hindwings. La Foa, October; Touho, October 3, 1940.

Diocalandra taitensis (Guer.)*: This small weevil is rather widely distributed in the Pacific. It breeds in the trunk, bases of leaves, spathe of the inflorescence and the young nuts. In some islands it sometimes causes severe damage to the palm. In the Hawaiian Islands it is not considered an important coconut pest.

Bronthispa longissima Gestro, var. *froggatti* Sharp°: This is one of the several hispid beetles that attack the foliage of the coconut palm in the East. It is a narrow flattened insect about 9–10 mm. long, and reddish and black in color (Fig. 10). Both

Fig. 10. Coconut hispid (*Bronthispa longissima* var. *froggatti*). Length 9.5 mm.

larva and mature beetle feed externally on the tender unexpanded leaves of the palm and thus do serious damage. I did not see this pest in quantity. It is found from New Guinea to New Hebrides (Simmonds, 1925). It also damages other species of palms. St. Louis and Mount Mou.

Plesispa cocotis Maulik°*: This is another hispid beetle. It is said to be less injurious than *Bronthispa.*

Necrobia rufipes (De Geer): This is the common widely distributed copra beetle. It is found about warehouses and copra-drying establishments.

Rhyncophorus ferrugineus Fabr.°*: The red palm weevil is one and one-half to one and three-quarters of an inch long. It usually follows up damage—such as wounds in the trunk—and the larva feeds within the trunk. It is considered a serious pest.

Oryctes sp.?°*: At Hienghene, on the east coast of New Caledonia, a note of October 4, 1940, is to the effect that the coconut palms showed occasional sheared fronds suggesting the work of this or another large dynastid beetle, although it may have

been the work of another type of insect. *Oryctes* beetles are serious coconut pests in Samoa, the East Indies and elsewhere. It seems not to have been recorded from New Caledonia.

Among the works relating to coconut pests of this part of the Pacific are:

Risbec, J., 1936. *Les parasites du Caféier en Nouvelle-Calédonie.* Agron. colon. No. 226: 105–123, 1 ref. Paris, October 1936.

Lever, R. J. A. W., 1934. *Entomology and agriculture in the British Solomon Islands.* Tropical Agri. 11:36–37.

Simmonds, H. W., 1925. *Pests and diseases of the coconut palm in the islands of the Southern Pacific.* Dept. Agri. Fiji, Bull. 16:1–32, 3 plates.

Other papers by various authors from the Department of Agriculture, Fiji, refer wholly or in part to coconut pests.

Coffee

Both *Coffea arabica* Linn. and *C. robusta* Linden are cultivated in New Caledonia. Small plantations were visited at Oua Tom, the Nepoui Valley on the west coast, and at Hienghene and Nakety on the east coast where it was more extensively planted. The groves visited were shaded by *Albizzia* and other trees and, as a rule, were situated at low levels. On the east coast the groves were often among coconut palms and but a short distance from the seashore. Small plantings were found in native villages. Generally speaking the bushes bore a healthy appearance with but few pests apparent.

Saissetia nigra (Nietn.): A few specimens of this armored scale—attended by ants—were found on the stem end of the berries. Hienghene, October.

Ueana lifuana (Montr.)°: This cicada is about one and one-fourth inches long. It seems this species chiefly that injures the coffee bush. The female cicada lays her eggs in the twigs which she pierces with her sharp ovipositor so that they may eventually break off. Such injured twigs were observed in a small coffee plantation at Oua Tom.

Moth°*: "The larvae of an unidentified moth made their galleries in the bark, and, when very numerous, ringed the trees or their branches, causing their death." (Rev. Applied Ent., 25:223, 1937, reviewing Risbec [1936].)

Coffearhynchus neocaledonicus Risbec°*: This coffee weevil was found by Risbec infesting the bark and branches of coffee in mountainous districts.

Araecerus fasciculatus (De Geer): This widespread tropical anthribid beetle is often destructive in stored coffee. It is also a feeder in dead wood, fruit husks, etc.

Enicodes fichteli Schreib, and *Enicodes montrouzieri* Montr.°: According to Risbec (1936) some New Caledonian coffee planters are of the opinion that the adults of these two longicorn beetles damage the fruits, but this was not confirmed; neither were the larvae considered injurious in coffee plantations. I found *Enicodes fichteli* rather abundant in wooded land in several localities, and at Hienghene it was beaten off coffee bushes which, however, it did not appear to damage. This insect is brownish black with some fine pale and more or less interrupted stripes. The male has much the wider head and the wing covers are attenuated in that sex. It measures up to an inch long.

Eulota similaris (Fer.) (Mollusca): This is a rather small, widely distributed tropical garden snail that is often a pest on vegetables and flowering plants. On Mr. Want's little coffee plantation at Oua Tom in September, this snail was present in large numbers at the bases of coffee bushes where it was evidently passing the dry season. It was considered injurious because it ate the bark at or near the ground.

J. Risbec has published a paper on the coffee pests of New Caledonia (*Les parasites du caféier en Nouvelle-Calédonie,* Agron. Colon. No. 226:105–123, 1 ref., Paris, October 1936).

Corn

Aphis maidis Fitch: Corn aphis. On corn. Col de la Pirogue, September.

Peregrinus maidis (Ashm.): Corn leafhopper. St. Louis, July, on sugar cane—sparse. Also on Johnson grass and a hairy, broad-bladed grass not identified. Isle of Pines, October, on sugar cane.

Heliothis armigera (Hubn.): Corn-ear worm. On various crops.
Marasmia trapezalis (Guen.)°: Corn leafroller. Generally distributed. This pyralid moth was not observed on corn.

Monolepta semiviolacea Fauv.°: This small leaf beetle is orange-yellow above and mostly blackish beneath. The disc of the thorax lacks a transverse groove. It is a bad pest on corn, turnips and other crops. Adults on the foliage, the larvae underground at roots.

Large Red-billed Coot (*Porphyrio* sp.?): In New Caledonia this bird or a related form is sometimes said to be a pest because it damages corn as seed in the ground, or on the cob. In times of drought banana plants are also injured.

Among beneficial insects frequenting corn plants are small anthocorid bugs.

Cotton

I examined a small planting of cotton at Oua Tom in September. Aphis and mealybugs were found at the bases of the squares or the bolls.

Oxycarena lugubris (Montr.)°: This small, chiefly black and white bug was found in bolls that had been eaten by pink cotton bollworms. The bug is common in Australia. In other countries related species are also associated with cotton, to which they do some damage.

Dysdercus sidae Montr.°: This is one of the cotton-stainer bugs. I took but few specimens in New Caledonia. It is a serious cotton pest in Queensland where Ballard and Evans found this as well as *Tectocoris lineolata* (Fabr.) to be: "... the chief insects that cause internal boll-rots and stained cotton." (Bul. Ent. Res., 18:405–432, 1928.) *D. sidae* is an Austro-Oriental species.

Tectocoris lineolata (Fabr.)°: This is a large stout bug of which there appear to be several varieties. It is orange-yellow with some markings of iridescent blue or green. It injures hibiscus and cotton and has been found on other plants. It did not appear common at the time of my visit. It is rather widely distributed in Australia.

For a treatise on this insect consult Ballard and Holdaway in Bull. Ent. Res., 16:329–346, 1926, illustrated.

Heliothis armigera (Hubn.): The corn-ear worm caterpillar attacks cotton, buds of roses, etc. It is often found in truck gardens.

Prodenia litura (Fabr.): The caterpillar of this armyworm is sometimes found on cotton.

Earias huegeli Rogenh.°: This is one of the bollworms and has been reported as the most serious cotton pest in New Caledonia. It occurs in Australia and well out in the Pacific. Risbec mentions a pentatomid bug as an enemy of this noctuid (*Un pentatome parasite de la chenille Epineuse du Cotonnier,* Compte Rendu Acad. Sci., France, 193:247–250, 1931).

Earias luteolaria Hamp.°: A single larva of a species of *Earias,* probably one of the above two species, was found on cotton at Oua Tom. Also in Ceylon and Queensland.

Platyedra scutigera Holdaway°: The pink bollworm of Queensland. The small, variegated brownish moth is closely related to the well-known pink bollworm (*P. gossypiella* Saunders). Moths were reared from cotton bolls at Oua Tom.

This insect was described from Queensland. For a discussion on this species the reader is referred to F. G. Holdaway—*The pink bollworm of Queensland,* Bull. Ent. Res. 17:67–83, 1926, 1 pl., 1 map.

Like other cotton pests in general this insect has other host plants related to cotton.

Tetranychus (*Eutetranychus*) *neocaledonicus* Andre°*: This acarid mite has been reported damaging cotton in New Caledonia.

Rice and Other Grasses

There seemed to be very little rice cultivated on the island. However, rice pests that also feed on other grasses were present. Some of these are:

Tettigonella spectra Distant°: A large pale leafhopper, also on sugar cane.

Nezara viridula (Linn.)°: Reported bad on rice in various tropical and sub-tropical countries.

Leptocorisa acuta Thunb.°: A rather large malodorous bug that is a well-known rice pest in the Orient.

Grasshoppers: Several species of short-horned grasshoppers that attack grasses in general.

Spodoptera mauritia (Boisd.): Armyworm.

Melanitis leda (Linn.)°: The caterpillar of this butterfly sometimes feeds on the rice plant.

Sugar Cane

Sugar cane was formerly cultivated in fairly large plantings in a few places in New Caledonia, but is now restricted almost entirely to very small patches in native

gardens. Striped varieties were common. It was frequently in rather poor condition, and insect pests, although usually not in large numbers on this plant, were often numerous in species.

Neomaskellia bergii (Sign.)°: This aleurodid was found on cane in Noumea and St. Louis but appeared to do little damage. It occurs in patches on the underside of the leaves. The adults are somewhat aphis-like, with broad wings irregularly marked in gray and off-white. The eggs are deposited in somewhat of a circle. The dark pupal cases are margined with white. The insect was usually attended by *Anoplolepis longipes* (Jerd.), an active brown ant not occurring in Hawaii.

This aleurodid is widely distributed in the East Indies and extends eastward in the Pacific as far as Samoa.

Aspidiotiform scale insect°: A single, little yellow scale insect found on sugar cane in a garden in Noumea.

(*Aphis sacchari* Zehnt., the common sugar cane aphis widespread in the Pacific, was not found in New Caledonia.)

Pseudococcus boninsis Kuwana: The gray sugar cane mealybug was the only species found on sugar cane. It was not abundant and was attacked by the ladybeetle *Cryptolaemus montrouzieri* Muls.

Eumetopina flavipes Muir°: A small rather slender delphacid leafhopper, mainly blackish above, and part of the body beneath pale yellowish (Fig. 11). It was gen-

Fig. 11. Sugar cane leafhopper (*Eumetopina flavipes*). Length 4.5 mm.

erally the most abundant of the several species of leafhoppers found on sugar cane. Its habits are much like *Perkinsiella* leafhoppers. It also occurs in the New Guinea area.

Perkinsiella rattlei Muir°: This delphacid leafhopper is a close relative of *P. saccharicida* that is found in Hawaii. It was quite scarce at the time of my visit, being taken at St. Louis, Nepoui, and Hienghene. It is probably this species or *Eumetopina flavipes* that is the vector of Fiji disease, widespread in New Caledonia.

P. rattlei was reported from New Caledonia by F. Muir (Ann. and Mag. Nat. Hist., 14 (10):578, 1934) from specimens collected by T. D. A. Cockerell in 1928.

Peregrinus maidis (Ashm.): The corn leafhopper was scarce, single specimens being taken at St. Louis and the Isle of Pines.

Tropidocephala sp. near *brunnipennis* Sign.°: On tall grass. Leafhoppers of this genus are common on sugar cane elsewhere. It is one of the Delphacidae.

Phaciocephalus rubrofasciata (Distant)°: This is a slender-winged, straw-colored derbid leafhopper (Fig. 12) with a brown and red stripe on the tegmina. It was often rather common on sugar cane but the young were never seen upon the plant.

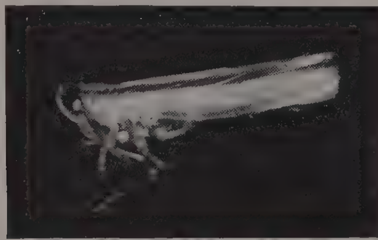


Fig. 12. Sugar cane derbid (*Phaciocephalus rubrofasciata*). Length 6 mm.

St. Louis and Hienghene. It was described as *Nisia rubrofasciata*° in Ann. and Mag. Nat. Hist., 6 (9) :462, 1920.

Phaciocephalus sp.: Two specimens from sugar cane near Houailou differ slightly from the above in their duskier wing stripe.

Phaciocephalus sp.°: A single specimen of a straw-yellow species with a black stripe taken on sugar cane on the Isle of Pines.

Eocenchrea sp.°: One specimen of this dusky derbid leafhopper was taken at St. Louis on sugar cane, on which it is most probably not specific.

Tetigoniella spectra Distant (=*Tettigonia albida* Sign.)°: This a large whitish-to-greenish yellow cicadellid leafhopper (Fig. 13), with four dark spots on the top of the head and the wing veins contrastingly dark. It is widely distributed in New

Fig. 13. Sugar cane leafhopper (*Tetigoniella spectra*). Length 9 mm.

Caledonia where it occurs on various grasses, including sugar cane. The immature leafhoppers were also seen on sugar cane, the adults being the more numerous on the plant. In India it is a common rice leafhopper. It is also found in the Australian region and extends into the Pacific as far as Fiji.

Ereunetis flavistriata Walsm.: Sugar cane bud moth. As in Hawaii the larva of this little moth feeds chiefly on the innerside of the cane sheath, usually a dry one;

less often it eats the surface of the rind and occasionally attacks a bud. The insect does little damage.

Cosmopteryx dulcivora Meyrick°: Sugar cane midrib leaf miner. The larva of this tiny narrow-winged moth bores the midrib in an irregular zigzag manner (Fig. 14) so that the affected part together with a little of the adjoining leaf tissue reddens and finally becomes dead and dry, even to the apex of the leaf. The insect, however,

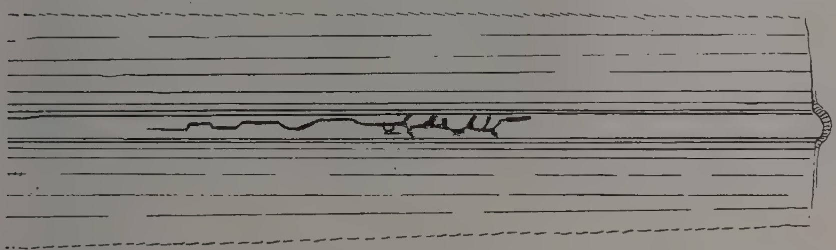


Fig. 14. Sugar cane midrib leaf miner (*Cosmopteryx dulcivora*) mine in section of sugar cane leaf. About natural size.

does only minor damage, and is held in some check by a hymenopterous parasite, a pupa of which was found in one of these mines. St. Louis and Hienghene.

Moth borer°: On October 5, near Ba-Houailou, in a small planting of red-stemmed Java cane, a small caterpillar was found in a dead top stubble. It had bored a short distance into the living tissue of this old cane stem. On October 8, at Nakety, another moth caterpillar was found under conditions similar to the first. In both cases the larvae seemed to be feeders primarily in rotting cane—or other plant tissue. Neither was reared.

Marasmia trapezalis (Guenee)°: This leafroller moth was occasionally seen. What may have been its caterpillar was observed tying together the younger leaves of a tall wild grass. Evidence of a leafroller was found on sugar cane in Noumea in late September. It is a well-known insect that also attacks corn but is not considered a serious pest.

Spodoptera mauritia (Boisd.): Armyworm. One adult moth taken at Noumea.

Melanitis leda (Linn.)°: This brown butterfly is widespread in the Orient, as one variety or another, and extends as far east as Samoa. The caterpillar feeds on various grasses—occasionally sugar cane, rice and corn. In New Caledonia the butterflies were seen about sugar cane in a native garden but none of the caterpillars was found (St. Louis). At Nepoui this crepuscular butterfly was seen laying its eggs on a large sedge that was growing alongside a wooded stream, and one adult was reared in this locality from a caterpillar found on this sedge. It is evidently of little or no importance on sugar cane. The writer saw a caterpillar of this butterfly feeding on sugar cane in Tutuila, Samoa, June 1940.

Calendra sp.°: Two specimens of a rather small undetermined weevil were found at Ba-Houailou resting on an injured portion of a sugar cane stalk. It is probably not a feeder in living plant tissue.

Tarsonemus mite ?: There was evidence of a stalk mite occurring very sparsely on sugar cane. The sugar cane leaf mite (*Tetranychus*) was not found.

Chelisoches morio (Fabr.): This is the same large and flat, black earwig that is so often seen on sugar cane in Hawaii. It is common in New Caledonia.

Ants: The most obvious ant on sugar cane in New Caledonia is *Anoplolepis longipes* (Jerd.).° It attends aleurodids and probably leafhoppers. Other ants found on this plant were *Prenolepis* (*Nylanderia*) *bourbonica* Forel, a species of *Pheidole,*° *Tapinoma melanocephalum* Fabr., *Cardiocondyla* and *Rhyzomyrma*° sp.?

Sugar Cane Diseases

Collections were made of sugar cane leaves and stem portions that showed signs of disease or of abnormal markings. These collections were submitted to J. P. Martin, pathologist at this Experiment Station for determination. It was found that Fiji disease was common and widespread in New Caledonia on sugar cane growing in native gardens. Eye spot and brown stripe were also present, as well as leaf burn. Good examples of sectional chlorosis were found in regions where the temperature was said to be at times relatively low.

Taro

A staple food of the indigenous people.

Aphis gossypii Glover: This common plant louse is found on taro and on many other plants.

Megamelus proserpina Kirk.: Taro leafhopper. Not seen in injurious numbers. Parasitized by a dryinid wasp and attacked by *Cyrtorhinus fulvus* Knight, an egg-sucking bug. St. Louis.

Fig. 15. Taro sphinx moth (*Hippotion celerio*). About natural size.

Prodenia litura (Fabr.)°: This armyworm feeds on several kinds of crops including taro. It was not a common insect at the time of my visit.

Hippotion celerio (Linn.)°: This handsome sphinx moth (Fig. 15) has a wing expanse of about three inches. It is of a general olive-brown color, the body and forewings marked with silvery dashes, the hind wings suffused with pink. The

caterpillar (Fig. 16) is brown or green with an eye-like spot on the swollen thorax and a horn above at the tail end. It is quite general on taro in New Caledonia and also on the ornamental Caladium plants of the same family. Frequently it almost

Fig. 16. Taro sphinx moth caterpillars.

defoliates these plants. This insect is widely distributed in the tropical Pacific as far east as Samoa, Tahiti and Moorea, occurring also in Africa, India, and parts of Europe.

A probable enemy of the caterpillar was noted at Nepoui, where a mass of braconid wasp (*Apanteles* ?) cocoons were found on a taro leaf near which the caterpillars were present.

Fig. 17. Bean bug (*Riptortus annulicornis*). Length 15 mm.

Fig. 18. Green vegetable bug (*Nezara viridula*). Length 16 mm.

R. J. A. W. Lever gives a good account of the taro sphinx in Fiji (Agric. Jour. Fiji, 11: 38–42, Ent. Notes. 1 fldg. plate, Suva, 1940). The damage that this insect does to taro is well figured by G. H. E. Hopkins (*Pests of economic plants in Samoa and other island groups*, Bull. Ent. Res. 18: 23–32, 1927).

Truck Crops

BEANS AND PEAS:

Aphids: On beans, Nepoui.

Aleurodidae: Adult white flies were sometimes found on beans.

Pseudococcus citri (Risso): This mealybug was found in rolled up leaves of pigeon peas.

Riptortus annulicornis (Boisd.)°: A large active bug (Fig. 17) that is quite common on climbing bean plants.

Nezara viridula (Linn.)°: Green vegetable bug (Fig. 18). On beans, cucurbits and other plants.

Leptoglossus australis (Fabr.)°: Mr. Swezey reports this large bug occasional on bean vines on the island of Guam. I found this insect quite rare in New Caledonia.

Nemashema modesta Montr.°: This small obscurely colored longicorn beetle may be beaten from bean vines, cotton plants and *Hibiscus tiliaceus*. It probably feeds on the dead stems.

Acrocerops sp.°: A tiny red caterpillar of a tineid moth that mines the bean leaves. It belongs to a group or a species widely distributed in Oceania.

Nacoleia diemalis (Guen.)°: A leafroller caterpillar (Fig. 19—moth) on beans. Nepoui.

Fig. 19. Bean leafroller moth (*Nacoleia diemalis*). Wing expanse 21 mm.

Plusia chalcites (Esper.): A looper caterpillar. On beans, Nepoui.

Heliothis armigera (Hubn.): Corn-ear worm. On peas, Noumea.

Cosmolyce baetica (Linn.): The blue bean butterfly. Not found to be common.

CABBAGES AND OTHER CRUCIFERS:

Cabbages and other crucifers are an important element in the truck gardens. We saw some mighty heads of cabbage in New Caledonia.

Brevicorne brassicae (Linn.): Cabbage aphis. Found on flowering head of turnip. St. Louis.

Hellula undalis (Fabr.): The cabbage webworm is a well-known pest in the Pacific. It was taken in the moth stage.

Liriomyza pusilla (Meig.): The maggot of this tiny black and yellow fly mines the leaves of many kinds of plants, including crucifers. As in Hawaii, it is often rather heavily parasitized by small wasps.

Monolepta semiviolacea Fauv°: This yellowish chrysomelid beetle attacks the leaves of crucifers and other plants. It is a serious garden pest.

Crocidoloma binotalis Zeller°: This is a destructive pest (Fig. 20) on Chinese cabbage and probably other crucifers. The work of the caterpillar among the younger leaves is very untidy.

Fig. 20. Moth on cabbage (*Crocidoloma binotalis*). Wing expanse 25 mm.

Helix aspersa Müll.°: This large European snail (Fig. 4) is common in gardens in New Caledonia where it sometimes does considerable damage to such vegetables as cabbage, wedging itself among the inner leaves and eating great holes in them. Observed in Noumea.

The British naturalist J. J. Walker who visited New Caledonia in 1900 speaks of the abundance of this snail in Noumea and the New Hebrides (Ent. Mo. Mag. 13 (ser. 2), 1901, page 190). It was introduced presumably to be eaten, as it was on the Pacific coast of the United States where it is likewise very injurious in gardens.

Veronicella leydigi Simroth: This large leathery black slug, widespread in the Orient, was observed on the east coast of New Caledonia. It is common in Honolulu where it sometimes injures low tender foliage.

CUCURBITS:

Aphis sp.: On squash, Noumea.

Leptoglossus australis (Fabr.)°: This large bug attacks various cucurbits and some other plants. Uncommon.

Nezara viridula (Linn.)°: Green vegetable bug (Fig. 18).

Fig. 21. Leaf beetle (*Aulacophora similis*). Length 6.5 mm.

Aulacophora similis Oliv.°: This beetle (Fig. 21) is a bad pest on Cucurbitaceae and other plants.

Monolepta semiviolacea Fauv.°: Somewhat resembling the preceding beetle. A pest on many crops.

SWEET POTATO:

The sweet potato is an important garden crop in New Caledonia.

Heliothis armigera (Hubn.): The corn-ear worm is occasionally found on sweet potatoes.

Herse convolvuli (Linn.)°: Morning-glory hawk moth. Several caterpillars of what was probably this species were found on sweet potato vines at Hienghene. The largest of these went into the ground to pupate but instead of a moth, yielded several large parasitic flies (Tachinidae). This sphinx moth is related to *Herse cingulata* (Fabr.), an American species found in Hawaii and which feeds on sweet potato and related plants.

Bedellia sp.°: A tiny moth the caterpillar of which mines the leaves of the sweet potato plant and pupates freely in a web on the leaf. It is closely related to *Bedellia orchidella* Walsm., the sweet potato leaf miner of Hawaii.

Batatarhynchus destructor Hustache°*: A sweet potato weevil reported attacking sweet potatoes in New Caledonia.

PLANTS OF THE TOMATO FAMILY:

Aleurodidae: White flies were occasionally seen on potato foliage. Noumea.

Empoasca flavescens (Fabr.): This is a tiny greenish leafhopper. On potato foliage, Noumea.

Mirid bug°: A small and delicate pale-green bug. On tomato, St. Louis.

Engytatus nicotianus (Konigsb.)°: Determined by Dr. R. L. Usinger. This bug is a tobacco pest. Taken on a species of white-flowered Datura.

Nezara viridula (Linn.)°: This insect (Fig. 18) was found damaging uncultivated tomatoes. Hienghene.

Prodenia litura (Fabr.)°:

Heliothis armigera (Hubn.): The caterpillars sometimes damage tobacco, tomato, and potatoes.

Fig. 22. *Sceliodes cordalis.* Expanse 28 mm. The caterpillar feeds on solanaceous plants.

Sceliodes cordalis (Dblb.)°: The reddish caterpillars of this pyralid moth (Fig. 22) have been recorded from the green berries of the potato in New Zealand, egg-plant in Australia, and they also attack related plants. At Noumea the caterpillars were found in the capsules of a white-flowered Datura.

Phthorimaea operculella (Zell.): Potato tuber moth. Caterpillars in potato plants, Noumea.

Termites or "White Ants"

G. F. Hill in his book *Termites* (Isoptera) *from the Australian Region* (Council for Scientific and Industrial Research, 1942, Melbourne) records six species of termites from New Caledonia, including the Loyalty Islands. Three or four of these and a new record were found on the present survey. There is little doubt but that additional species are present on this island. No termite mounds, such as occur in great abundance and variety in Australia, were seen in New Caledonia, although two small mounds that I took to be fallen, semi-carton nests were found in the Thi River forest near St. Louis. Termites were secured from these nests.

The New Caledonian termites are as follows:

Calotermes (*Neotermes*) *rouxi* N. & K. Holmgren°: In dead branch and at light. The determination of this termite is not certain. Noumea and an islet near Yate, October.

Calotermes (*Neotermes*) *sarasini* N. & K. Holmgren°: I took a winged adult of what appears to be this species. Thi River forest, November. Recorded by Demant (1914) as a pest of cacao in Samoa. (See G. H. E. Hopkins *Pests of Economic Plants in Samoa and Other Island Groups,* Bull. Ent. Res. 18: 23–32, 1927.)

Calotermes (*Neotermes*) *semilunaris* N. & K. Holmgren°*: Recorded from the Loyalty Islands.

Calotermes (*Cryptotermes*) *albipes* Holmgren°*: Recorded from New Caledonia and the Loyalty Islands.

Calotermes (*Cryptotermes*) *canalensis* N. & K. Holmgren°: In dead branch, Noumea. It is probably a species of *Cryptotermes* that damages buildings in Noumea.

Prohinotermes inopinatus Silvestri°: Specimens were taken at Prony Bay in October. Apparently a new record for the island. Found also in Samoa and Fiji.

Microceratermes novae-caledoniae N. & K. Holmgren°: Yahoue Valley, August, under stone; Thi River valley, from two semi-carton nests. Again from G. H. Hill's book, on page 437, I quote: "*Biology.* Holmgren records one of his series as having been found in an earthy nest about a half metre high."

Miscellaneous

Leafhopper°: A tiny green cicadellid leafhopper was found in moderate numbers on turnips and carrots.

Hymenia recurvalis (Fabr.): As in Hawaii the glassy-green caterpillar of the amaranth webworm is a pest on spinach. It also feeds on *Portulaca.*

Short-horned grasshoppers or locusts: Grasshoppers have done considerable damage to pasture lands, sugar cane and other crops. I did not see grasshoppers in epidemic proportions. About the dry grassy hills of Noumea particularly, one medium-large and three large species were noted, as follows: *Ailopus tamulus* (Fabr.)°:

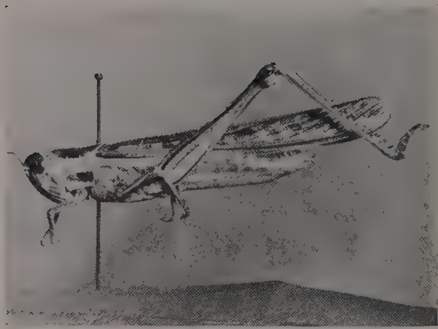


Fig. 23. *Austracris guttulosa illepida.* Length from head to wing tips 55 mm.

What appeared to be this medium large species was common. *Austracris guttulosa illepida* (Walk.) (=*Acridium neo-caledonicum* Finot)°: A slender long-winged species (Fig. 23) with pale stripes on thorax and outer wings. Among grass. A specimen observed ovipositing in a path. This insect has much the appearance of the bird-wing locusts (*Schistocerca*) of America. *Valanga rouxi* Willemse°: A large rather thickset, chiefly brownish gray insect with speckled wings. It seems addicted to trees and shrubs rather than to keeping on the ground. *Locusta migratoria danica* (Linn.)°: A large heavy species with a rather sharply crested pronotum and some green on head, thorax, and hind legs, the tibiae of which are bright red. One of the famous migratory locusts of the old world.

Lantana Insects: Both the lantana leaf bug (*Teleonema scrupulosa* Stal.) and the lantana seed fly (*Ophiomyia lantanae* [Froggatt]) were found well established on *Lantana camara* at Noumea. These two insects were introduced from Fiji to which islands they were brought from Hawaii.

Cactoblastis cactorum Berg: This pyralid moth borer in Opuntia cactus introduced from Australia has done good work here.

Nutgrass (*Cyperus rotundus* Linn.) enemies: *Bactra truculenta* Meyr., the common nut grass moth borer was reared from nut grass at Noumea. An undetermined moth borer, somewhat resembling the above was also reared from nut grass at Noumea.

Milkweed (*Asclepias curassavica* Linn.): This weed with pretty orange-red flowers is well distributed in the island but seemed not to be a pest. The relative scarcity of this plant has been attributed to the attacks of the larva of a lepidopterous insect called *Papilio leratii*. See *The Macrolepidopteron, Papilio leratii, as a natural means of controlling Asclepias curassavica, a weed growing in New Caledonia,* Paladini, F. (Sr.), Revue agricole, 77: 3–4, Noumea, February 1922, from Review of Science and Practice of Agriculture, Inter. Inst. of Agric., Rome, 13: 773, 1922. This savors largely of the monarch butterfly, *Danaus plexippus* (Linn.), which is found in New Caledonia.

Aphis nerii (Fonscolombe [=*A. lutescens* Monell]) was found on this milkweed.

Arctiid moths: The caterpillars of two arctiid moths, *Argina cribraria* Clerck, orange-yellow with black spots, and *Utetheisa pulchelloides* Hamp., form *stigmata* Roths (Fig. 24), white, red and black, attack various plants. *Argina cribraria* is a pest of sunn hemp in India.

Fig. 24. *Utetheisa pulchelloides,* form *stigmata.* Wing expanse 36 mm.

Euproctis sp. (Lymantridae)°: This is a small species of brown-tail moth; the female is white and the male brownish with plumose antennae (Figs. 25, 26). It was found common on shade trees, chiefly *Delonix regia* (Bojer) in Noumea. Its hairy caterpillar spins a whitish cocoon found singly or in groups on the tree trunks. Other and larger cocoons on or under the bark of shade trees indicate the presence in season of additional harmful caterpillars.

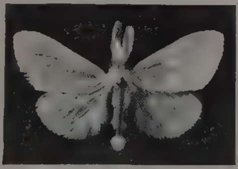


Fig. 25. Brown tail moth *Euproctis* sp., male. Wing expanse 18 mm.

Bagworms (Psychidae)°: Large bagworm cases were found suspended on trees.

Noctuid Caterpillar: On water hyacinth (*Eichhornia*). In Noumea a variegated moth caterpillar was observed eating the pseudobulbs of this plant.

Asplenium fern moth°: Caterpillars of a pyralid moth hatching from a mass of

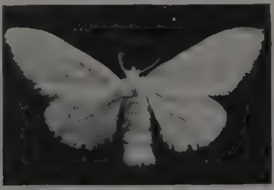


Fig. 26. Brown tail moth, *Euproctis* sp., female. Wing expanse 23 mm.

imbricated eggs attack the fronds of the bird's nest ferns in the forest (Figs. 27, 28). The caterpillars, at least at first, feed gregariously on the underside of the fronds, eating out unsightly patches (Fig. 29). The young caterpillars have black heads and glassy-green bodies; later on, the head is only speckled with dark while the body is rather sparsely provided with stiff black hairs.

Fig. 27. Caterpillar on bird's nest fern (*Asplenium* sp.). Length about 9 mm.

Fig. 28. Pupa on bird's nest fern (*Asplenium* sp.). Length 7 mm.

Staghorn Fern (*Platycerium*): This fern which grows wild in the forest is often seen in gardens and parks. An aphid (*Myzus* sp.)° was found on it at Noumea.

Orchid Pests: A certain wide-leafed ground orchid was found infested by the scale *Saissetia hemispherica* (Targ.), while in the thickish leaves of *Dendrobium* sp. were found the mines of a tiny caterpillar,° several dried up little moths with banded wings being present in the emergence chambers. Doubtless there are many other insects harmful to the numerous species of Orchidaceae found in New Caledonia.

Xystrocera globosa Oliv.: This is a rather large longicorn beetle that inhabits many Pacific islands. Remains of a dead adult and several grubs were found in the trunk of a dead peach tree in a garden in Noumea. The insect is a feeder in dead or unhealthy timber.

Skipper Butterfly (*Badamia exclamationis* [Fabr.])°: The "badamier" or tropical almond (*Terminalia catappa* Linn.), our "false kamani," is the food plant of the caterpillar of this swiftly flying butterfly (Figs. 30, adult; 31, caterpillar; 32, pupae). The eggs are at first green but eventually turn bright red. The caterpillar when well grown is a striking insect with its orange head and greenish yellow body that is strongly striped and banded with black. It makes a retreat, folding over the edge of a leaf or fastening portions of leaves together. The mealy pupa is formed in such a retreat. A small potted *Terminalia* tree in the hotel garden was almost defoliated by successive broods of this caterpillar, few of which however appeared to transform into butterflies.

INSECTS ATTACKING FOREST TREES:

A few fragmentary notes are offered here.

Fig. 29. Damage done by caterpillar to Asplenium fern.

Fig. 30. *Badamia exclamationis*, skipper butterfly on *Terminalia catappa*. Wing expanse 50 mm.

Fig. 31. *Badamia exclamationis* caterpillar. Length about 30 mm.

Fig. 32. *Badamia exclamationis* pupae. Length 20 mm.

The tall "pin colonnaire" (*Araucaria Cookii*) a conspicuous tree in certain lowlands of New Caledonia, and particularly on the coral islets to the south, is much employed in coarser building work. The lumber is sometimes damaged by a large grub° which makes borings that are oval in cross section. Considerable quantities of coarse sawdust may be found under such infested wood. The culprit is probably the grub of a very large cerambycid beetle, and I was informed by a lumberman on the Isle of Pines that this insect works in the logs with a very audible crunch-crunch!

A small species of *Grevillea* which grew on the mineralized soil had some of its leaves mined by the larva of a small moth.° An eulophid wasp bred from such leaves was probably parasitic on the caterpillar.

There are several species of *Casuarina* in New Caledonia. On the hills behind Noumea are individual trees or thickets of the small *Casuarina collina* (?) upon which one finds a tiny buprestid beetle; a white diaspine scale; the caterpillars of one or more species of geometrid moths; while a cecidomyid midge is often associated with gall formation on the fine twigs. A larger species of *Casuarina* bears larger galls on woody branches and these also appear to be associated with a midge.

The Indian wax scale (*Ceroplastes ceriferus* [Anderson]),° (Fig. 33), occurs on bracken fern (*Pteridium sp.*) and on the branches of shrubs in mineralized areas. This sticky, white scale, which may occur in large compact groups on the plants, is conspicuous for quite a distance, and my first view of it was in scanning a hillside from the automobile carrying us across the central mountain chain.

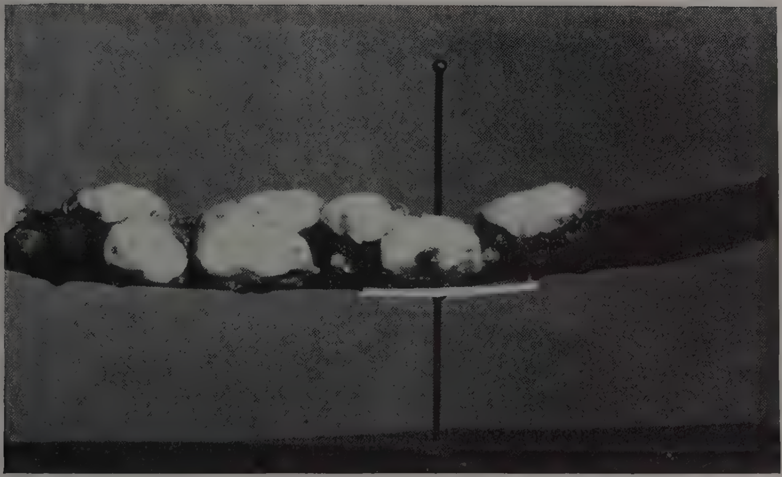


Fig. 33. Indian wax scale (*Ceroplastes ceriferus*).

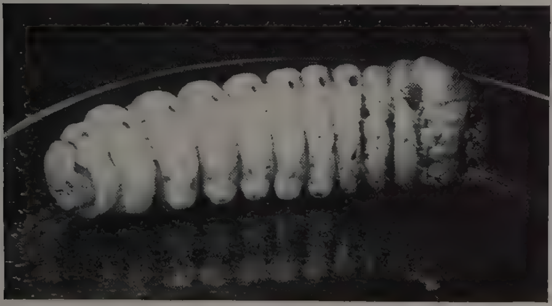


Fig. 34. Grub of a large longicorn beetle in *Aleurites* sp.

The "bancoulier," which is our kukui tree (*Aleurites moluccana* Willd.) is abundant in New Caledonia, and fallen and decaying specimens are a veritable gold mine for the entomologist, particularly to the searcher after beetles. The trunk of dead trees are commonly bored by the very large grub (Fig. 34) of a longicorn beetle. The larva and pupa of this beetle are considered a delicacy by the Melanesians and are also much sought after by the crows. Between these two hazards and the visiting entomologist this beetle should fare badly. Before pupating the grub cuts a lidded door in the bark (Fig. 35) to facilitate the exit of the adult. Such lidded doors are also made by other species of longicorns such as *Lagocheirus obsoletus* Thoms. in the Hawaiian Islands.

The niaouli tree (*Melaleuca leucadendron* var. *viridiflora*) is attacked by many species of insects, which together with their enemies and other associates combine to form a very interesting biota. Some of these organisms are: The scale *Ceroplastes rubens* Mask. is common on the leaves, and its presence is often indicated by black smut. The caterpillars of at least three species of moths are attached to this tree;

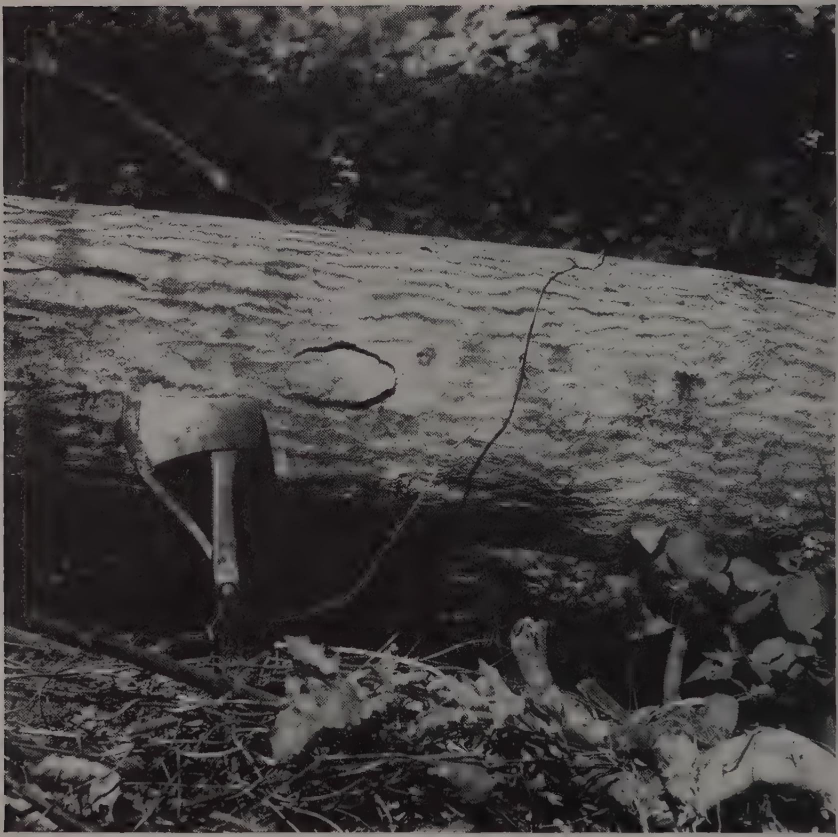


Fig. 35. Aleurites log showing oval lidded door of pupal chamber of longicorn beetle.

the largest of these moths is a noctuid, evidently near the genus *Anua*° (I was unable to secure good specimens for proper identification). Its wood-brown caterpillar attains a length of two inches and is of the semi-looping type. It hides singly or in small groups under the loose bark, its presence there being often indicated by the considerable quantity of frass beneath at the base of the tree. The caterpillar comes out at night to feed upon the leaves. A weak cocoon is formed under the bark which often causes a telltale bulge at that point. The pupa is dark and stout. Hatched or dead pupae of a smaller moth° are often found beneath the bark. Apparently feeding in the layered bark is a small greenish moth° larva with small dark plates on its body (Fig. 36). At the time of my visit most of these caterpillars were in a quiescent state in cocoons in the bark. Some hatched pupae were found in the cocoon chambers which connected with the exterior by means of a little flap door cut out of the bark.

The timber of this tree sometimes shows cylindrical beetle borings.

The blossoms furnish honey for the honey bee and attract many other insects as well as the flying foxes or fruit-eating bats (*Pteropus*).

A host of enemies prey upon these *Melaleuca* insects. Large tachinid flies and ichneumonid wasps (*Ecthromorpha*) attack the larva and pupa of the large moth (*Anua*) (?). This moth may be found entangled in the web of a large spider (*Nephila* sp.) common in the loose niaouli forests; or the moth is to be seen skewered on the thorns of the leguminous shrub, *Acacia farnesiana*. Large centipedes probably feed upon these various caterpillars, while crows are said to frequently shred the bark in searching for the larvae and pupae. The larva of a large elaterid or click beetle was often found beneath the bark sometimes to a height of at least three feet up the trunk, where it no doubt fed upon the various larvae it

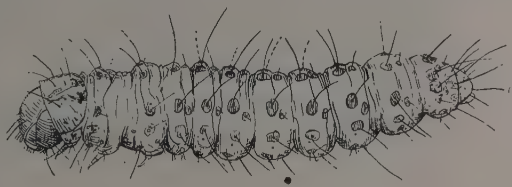


Fig. 36. Niaouli bark caterpillar. Much enlarged.

encountered. The small lepidopterous larva, often so abundant in the bark, was apparently parasitized by two large chalcidid wasps, of which one with a very long ovipositor could frequently be seen exploring the trunks or boring through the bark. Finally, a little wasp of the genus *Sclerodermus* was sometimes seen attacking these small caterpillars among their cocoons.

The honey bee (*Apis mellifera* Linn.) is kept in domestication but is abundant in the wild state, and in my rambles bee trees were continually discovered. Species of banyans (*Ficus*) were frequently thus appropriated. The bee finds pasturage on lantana, casuarina and other plants, but the honey industry is said to depend very largely upon the blossoming of the niaouli. This widespread tree was only in sporadic bloom at the time of my visit, and the farmer-apiarist from whom I desired to purchase honey had hardly any available.

SPIDERS AND OTHER ARTHROPODS:

Nephila sp.°: This is a large spider with a pale olive-brown abdomen. It is common in the open *Melaleuca* forests where it spins a strong vertical web that entraps many flying insects, conspicuous among which is the honey bee.

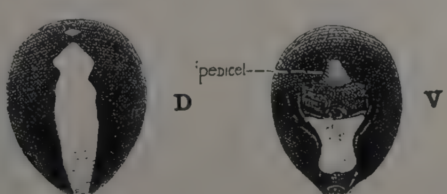


Fig. 37. Black widow spider (*Latrodectus hasseltii*) abdomen: D, dorsal; V, ventral. Enlarged.

Latrodectus hasseltii Thorell°: This Australasian and Indonesian spider (Fig. 37) is known in Australia as the red-backed, red-striped or jockey spider, and in New Zealand as the katipo. It is widespread and common in the lowlands of New Cale-

donia, its irregular webs being found on the underhanging sides of boulders and other shelters. On the Isle of Pines it was found in numbers on the base of niaouli (*Melaleuca*) tree trunks, where it was concealed among the loose bark. This spider is related to the black-widow spider (*Latrodectus mactans* [Fabr.]) of America, and appears to be quite as venemous and evidently so recognized by the natives. In addition to the red hour-glass-shaped spot on the underside of the abdomen, there is a broad rather variable stripe on the back or dorsum and that is not characteristic of *L. mactans.* The egg cocoons of both species are very similar.

Some of the literature referring to *Latrodectus hasseltii* follows:

A. Musgrave, *Some poisonous Australian spiders* (Records of the Australian Museum, 16: 33–46, 1927; J. Vellard, *Le venin des araignees* (Monographies de L'Institute Pasteur, 1936; and Berta S. Gerschman and Rita D. Schiapelli, *Revision del genero Latrodectus* Walkenaer, 1805, Reimpresion del Museo Argentino de Ciencias Naturales, 1943).

Isometrus maculatus De Geer: This scorpion is a rather small brownish species also found in Hawaii. It occurs under bark and debris and its sting is not regarded as serious. *Hormurus australasiae* Fabr. is a larger and more heavily built dusky species with stout chelae or hands and relatively short tail. It is common under logs and stones in the forest but is not aggressive.

Scolopendra subspinipes Leach: This large centipede (millepatte) is also found in Hawaii and in many other Pacific Islands. It was common around Noumea, hiding under objects lying on the ground and under the bark of the niaouli trees. Another species of centipede of rather large size and with the most posterior pair of legs very stout and curved is found in the forest.

Vegetative Differences Influence the Composition Of Sugar Cane*

By A. H. Cornelison

The cane and sugar yield differences found to exist, under identical conditions of culture, between the three varieties of cane studied in this experiment are interpreted as being caused more by vegetative time and type responses than by wide absolute differences in photosynthetic and storage capacity differences.

In view of the fact that our prior studies on the effect of nitrogen on the cane plant (2, 3, 5) were carried out using the variety H 109, it was thought highly advisable to learn how this cane compared in physiological habits with other varieties growing under similar conditions.

In planning the experiment our objective was primarily to obtain information on the genetic characteristics of several varieties, using a "standard" variety with which we were partially familiar for comparison. We were able to obtain three genetically related varieties of commercial plantation standing—H 109, POJ 2878, and 31–1389—that met this requirement nicely. Field weights and census figures; Cuba mill juice samples; glucose, sucrose and total sugars on the dry-cane basis, and certain physico-chemical measurements were to be used to furnish the data for comparisons of physiological habits of the three varieties. They are discussed under their individual titles in this paper so will not be elaborated upon here.

For those interested in the techniques employed, attention is directed to the papers noted in the first paragraph, as the methods employed therein were identical with the ones used in this experiment. The descriptions are too lengthy to repeat here.

Plan and Experimental Procedure

The experimental area was located on the grounds of the Experiment Station at Makiki. The soil was plowed, harrowed and lined into nine plots, each plot consisting of seven 20-foot by 5-foot lines, each line comprising an area of .002275 acre. The soil in each plot was sampled and tested for available nitrogen, phosphate, and potash prior to planting and all were found reasonably uniform. Seed for the area was obtained from plantations on Oahu and its germination occurred within three weeks of planting.

Plan

The plan for the test was to run bimonthly harvests from one line of each variety, harvesting all cane in the line. The canes were to be grouped by age of emergence in the field and, in the case of first-appearing "primary" stalks, into chronological age

* Variety Test No. 1 (Preliminary), Project D-1—Biochemical Laboratory.

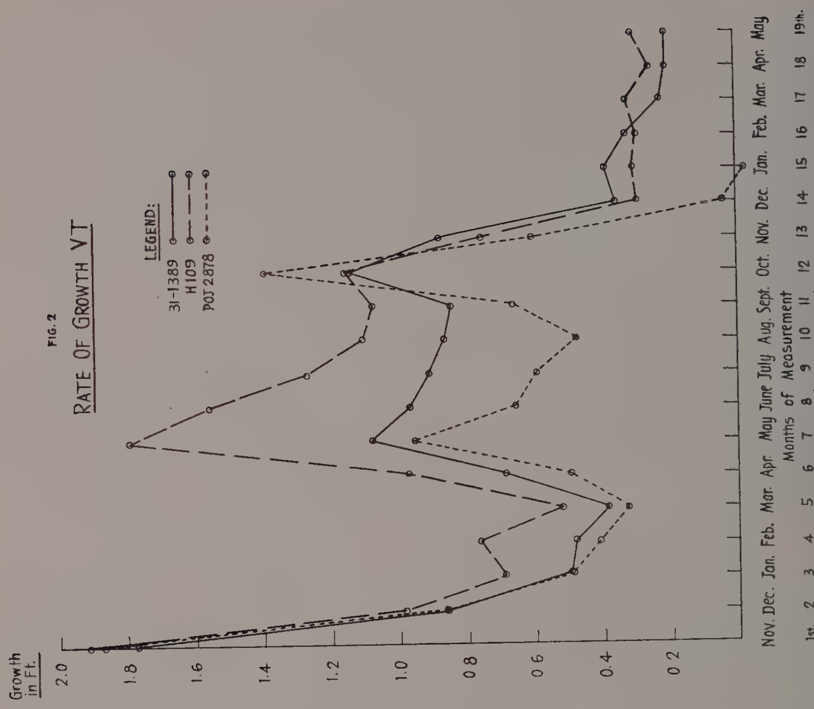


FIG. 2
RATE OF GROWTH VT
LEGEND:
31-1389
H109
POJ 2878
Growth in Ft.
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May
Months of Measurement
1st. 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19th.
Number of Measurement

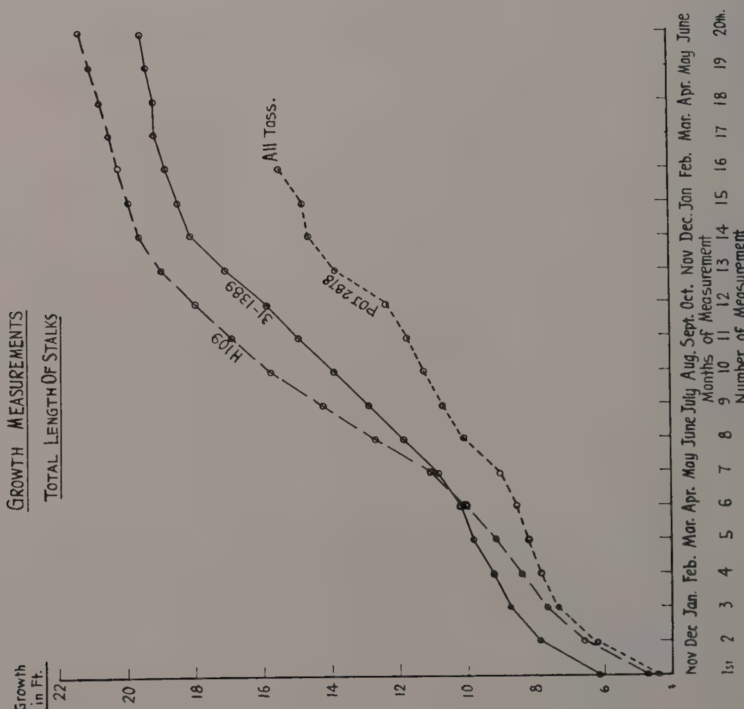


FIG. 1
GROWTH MEASUREMENTS
TOTAL LENGTH OF STALKS
Growth in Ft.
22
20
18
16
14
12
10
8
6
4
All Tass.
31-1389
H109
POJ 2878
Nov Dec Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov Dec. Jan Feb. Mar. Apr. May June
Months of Measurement
1st 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20th.
Number of Measurement

sections which were marked with paint, thereby dividing the stalk into four-month seasonally formed groups. Various field measurements, chemical and physico-chemical, and other determinations were to be run on the different samples collected. These diverse determinations will be dealt with in detail later.

Agronomy:

The germination of the seed pieces in this area was poorer than in the fertilizer experiment areas adjacent, partially due to somewhat poorer soil conditions but largely due to non-viable and damaged eyes, especially in variety 31–1389. Replant was necessitated in the plots and for some months these canes were naturally more retarded in development than the original. Before the first fertilization, the area had been thoroughly rogued of all stools affected with mosaic and chlorotic streak, and replanted with healthy, previously germinated seed pieces. The field was generally yellow-green in color prior to the first fertilizer application, but within two weeks it became a normal green and at no time thereafter were there any leaf indications of nutritional disturbances or shortages. (Reference is invited to the title "Nitrogen Content of Cane" later in this paper for discussion regarding this subject.) Eye spot disease appeared in H 109 during the first fall, but none of the other varieties showed any recognizable lesions and the entire area was free of other disease symptoms.

Fertilization and Irrigation:

Irrigation in the amount of 16 inches per month was applied throughout the crop life in the form of two 2-inch irrigations per week. If rainfall of over half an inch was recorded, the irrigation was approximately adjusted to account for it in the schedule. This amount of water is considerably more than is needed to keep the soil above the wilting point at Makiki.

Fertilization of all plots was carried out according to the normal plantation practice of one application at 1½ months, furnishing 50 pounds per acre of nitrogen and 200 pounds per acre of potash and of phosphate, followed by a fall application of 125 pounds per acre of nitrogen; and in March of the following year another application of 75 pounds of nitrogen was applied. The nitrogen was applied from ammonium sulfate, the potash from potassium chloride, and the phosphate from calcium superphosphate. An unavoidable difficulty is faced in undertaking a variety test of this type in that the fertilizer requirements of two of the varieties may be different from those of the standard or optimum for the other variety, thereby unfairly influencing yields of new, unfamiliar varieties.

Growth and Stand of Cane:

Seed pieces for the test were of necessity obtained from different localities on Oahu and in transportation a certain amount of damage to eyes was incurred. In variety 31–1389 many eyes were found to be non-viable and in many cases no eyes were present. (This is an odd circumstance as lack of eyes is normally associated with cane which has started to arrow in the early fall and is not normally found in spring-formed tissue, as pertained in this case.)

Thus, soon after germination, it became obvious that very erratic stands were present in the plots. After replants were inserted and all positive measures were

FIG. 3

Millable 1st Order As Per Cent Of Total Millable

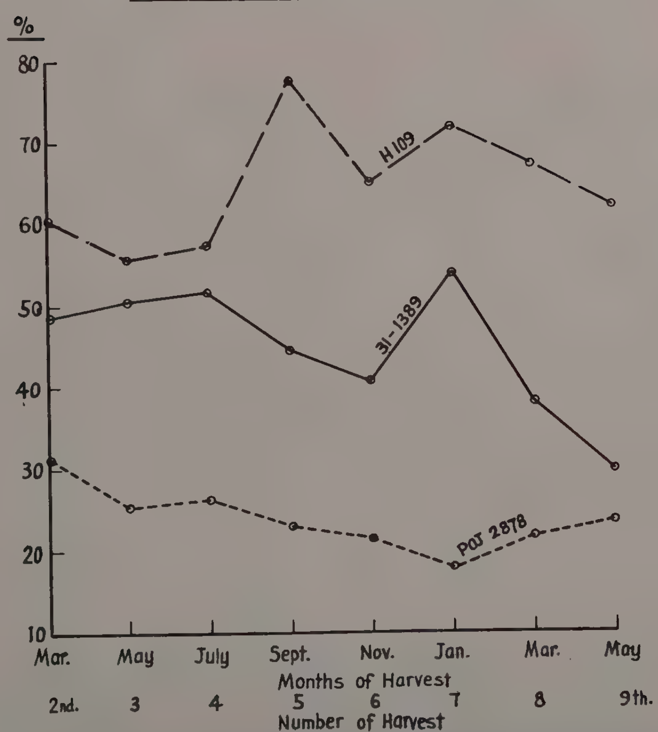
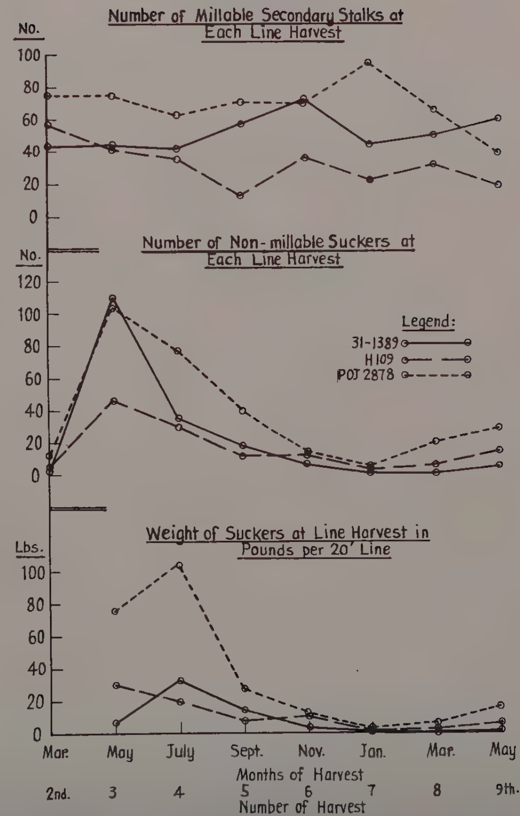


FIG. 4

VARIETY TEST 1



taken to insure uniformity, we judged it expedient to take negative measures to obtain uniform populations in all plots and lines, and did so by excision of shoots so as to arrive at 2.75 shoots per running foot of line (55 per 20-foot line). This figure was derived from final harvest data for the area from a former H 109 crop. We realized we had possibly imposed artificial restrictions on the heavier tillering varieties, but no other method of equalization of the initial disadvantage was apparent. The 55 primary shoots were tagged in each line and will be known henceforth as "first-order stalks" in this report.

All stalks which started at a date four months or later after planting are classified as "secondaries" if they have formed millable cane or "suckers" if at any harvest they were in a non-millable condition or state of growth.

Additionally, the first-order stalks were marked on the node of attachment of the last visible unfurled leaf exposed at the ages of four, and eight months, making two age groups of fixed seasonally formed composition. The parts of the stalk that were in some cases not fully mature (or after eight months not falling into the two aforementioned categories) were classed as "dry leaf," "green leaf," and "non-millable top," as was done in the fertilizer tests. For the collection of data, secondaries were divided into the three latter classifications only, as the heavy stands in the field precluded further work "inside the cane" at the time they arrived at the marking status.

Growth observation was made at frequent intervals and varietal habits were readily identifiable. Both POJ 2878 and 31–1389 made rapid growth and "closed in" about two months ahead of H 109. Also it was soon apparent that POJ 2878 and 31–1389 were both making much greater amounts of millable cane in the first four months than was H 109. As the cooler weather of fall took effect, all three canes slowed down in rate of elongation and a noticeable difference in top type in the varieties became apparent. The top of H 109 was thick, sturdy and well leafed, while both of the other varieties not only suffered shortening of inter-nodes (as did also H 109 to a lesser degree), but the diameter and strength of both were so reduced that winter winds caused more damage to them than in the case of H 109. Tasseling was light in all plots but was greatest in POJ 2878, followed by 31–1389 and H 109 in decreasing order of incidence. When warmer spring weather began to prevail, H 109 with its well-established sturdy top was in better fettle and responded immediately, soon passing the other varieties in rates of elongation and weights of primary stalks. Both POJ 2878 and 31–1389 initiated considerable new sucker growth in this period and, in the case of POJ 2878, senescence of the primary stalks became marked. There was not this large dying back of stalks in 31–1389, as was present in POJ 2878, even though secondaries were initiated at this period. "Going down" occurred in early December in all varieties, but it was especially noticeable that the primaries in 31–1389, either due to stronger root systems or stalk structures, resisted this condition and many remained practically vertical.

By general observations of growth habits, it might be said that POJ 2878 in a 12-month period produces one crop and in the following period produces another crop of secondaries, which in the final harvest at 24 months makes up much the greatest part of the crop harvested. Primaries in POJ 2878 do not carry over well. Contrary to this, 31–1389 appears to be a variety which could be harvested at about

FIG. 5

VARIETY TEST

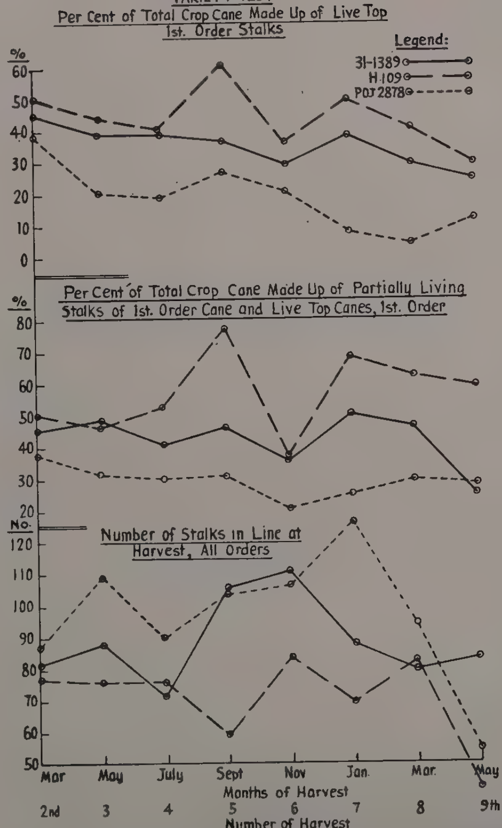


FIG. 6

VARIETY TEST

Total Weight of Millable Cane in Secondary Stalks at Each Line Harvest

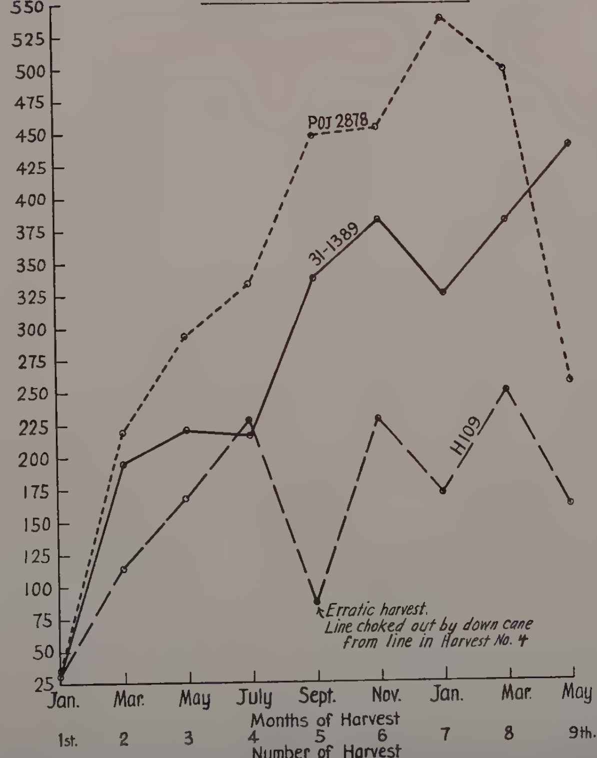
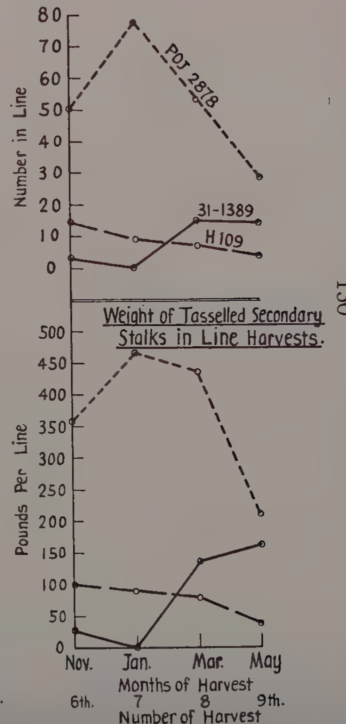


FIG. 7

VARIETY TEST

Number of Tasselled Secondary Stalks in Line Harvests.



12 to 16 months of age or, if not cut then, should be allowed to remain until its secondaries become millable and ripe. These 31–1389 primaries appear to carry over fairly well. In H 109 the crops were made up largely of primaries even at 24 months and large weight increases were made in primary stalks in the second year. These differences in vegetative habits would have a great effect on any composited juice sample taken for comparative studies.

Character and Rate of Elongation (Figs. 1 and 2):

Twenty-five first-order stalks were selected in one interior line of each variety, and monthly total elongation, and rate of elongation measurements, were made on these stalks, the procedure being the same as in the previously reported nitrogen tests. As was noted in the reports on the nitrogen tests, certain errors enter the data, but discussion of these will be omitted here. No measurements were made until the crop was five months old when it was possible to select 25 representative primaries for study. Study of the secondary population was not possible, due to shortage of manpower and time.

At the time of the first measurement, due to the effects of fall and winter weather, the rates of elongation in all varieties were dropping at approximately the same general rates, although there is a rather definite indication that H 109 has a bit lower temperature or light threshold value for growth than the other two, as it holds a slightly higher elongation rate than the other two varieties during the winter. The size of top, noted previously, may have some influence on this, and the findings may be more closely bound up with a physiological age factor for growth than a difference in response to temperature levels. Several variety tests planted at different seasons would probably determine the relative importance of these two factors.

The increasing length of day and temperature of spring caused noticeable increases in growth (elongation rates) in all varieties but were most effective in H 109. The very high rates attained in May are probably attributable to the nitrogen application put on two months earlier, as the May peak rate is followed by a subsidence in rates of all varieties, although temperature and length of day actually increased for a month and a half after the rate peak was reached. Some conclusions on this will be discussed later under the title "Nitrogen Content of Cane." As will be noted from the graphs, growth rates dropped rapidly after December of the second year and we read from this that physiological age has here become the limiting factor.

Tillering and Secondary Canes (Figs. 3 to 7):

Heavy secondary stands were initiated in both POJ 2878 and 31–1389 in May of the second season and were classed as non-millable suckers until about September, at which time most of them had entered the millable secondary class. H 109, by comparison, started less than half as many suckers or tillers as did the other two canes and, by the onset of winter, a large proportion of these were fairly mature canes in vegetative appearance, although poorer in juice quality than the primary stalks.

Although all varieties were eventually started with uniform stands, POJ 2878 developed a larger number of sticks per foot of line than did the other two, and an inspection of Figs. 3, 4, and 5 will show that for a considerable period of the second

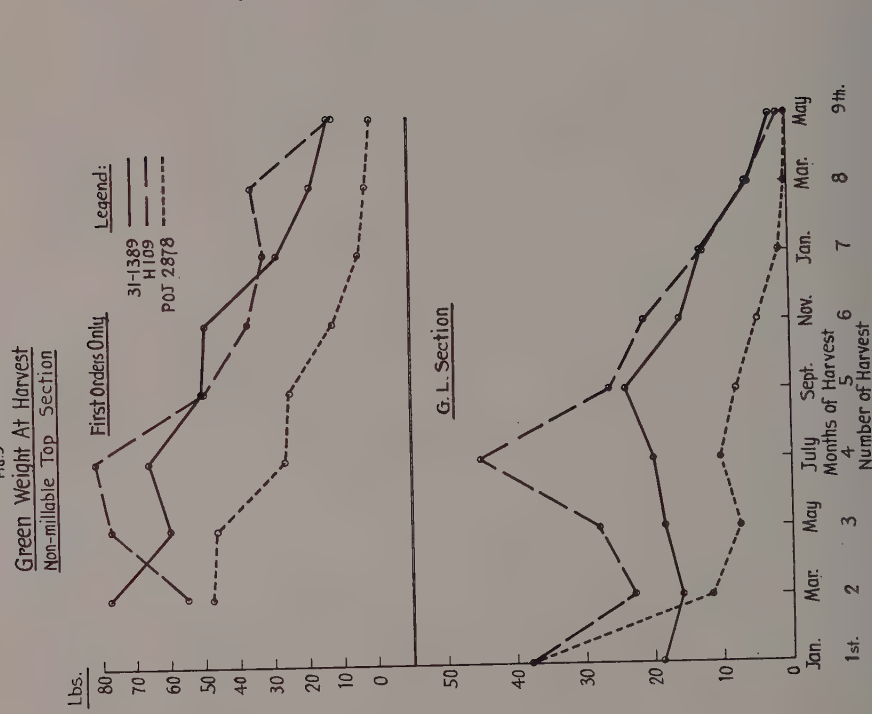


FIG. 9
Green Weight At Harvest
Non-millable Top Section
First Orders Only
Legend:
31-1389
H 109
POJ 2878
Lbs.
80
70
60
50
40
30
20
10
0
G. L. Section
50
40
30
20
10
0
Jan. Mar. May July Sept. Nov. Jan. Mar. May
Months of Harvest
1st. 2 3 4 5 6 7 8 9th.
Number of Harvest

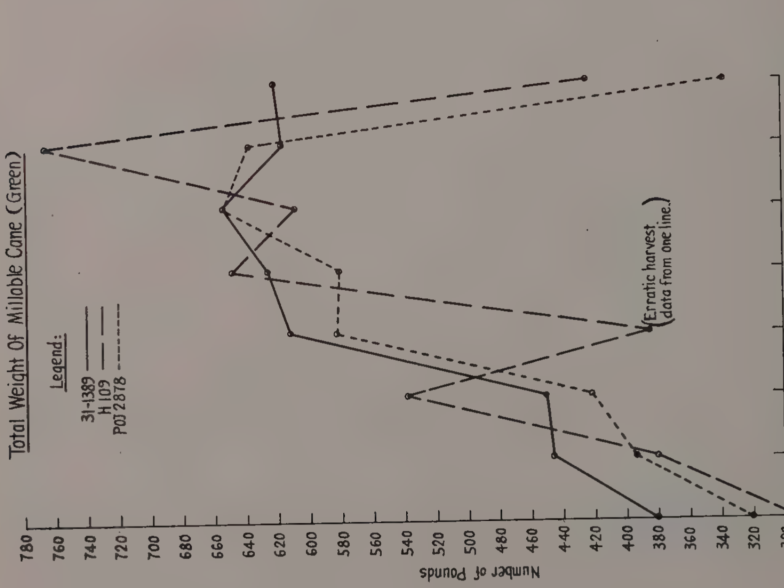


FIG. 8
Total Weight Of Millable Cane (Green)
Legend:
31-1389
H 109
POJ 2878
Number of Pounds
780
760
740
720
700
680
660
640
620
600
580
560
540
520
500
480
460
440
420
400
380
360
340
320
300
(Erratic harvest, data from one line.)
Mar. May July Sept. Nov. Jan. Mar. May
Months of Harvest
2nd. 3 4 5 6 7 8 9th.
Number of Harvest

season less than 30 per cent by number of the POJ 2878 crop in the field consisted of primaries. In 31–1389 during the second season the crop is roughly half and half, primaries and secondaries, while H 109 is, as usual, made up of about 65 per cent primaries, similar to results obtained in our former work.

We fully recognized the possibility that our excision of shoots for equalization of stands may have forced the heavy stooling varieties to send up the larger proportions of secondaries and, in a more comprehensive test following this preliminary one, allowance was made for such a condition to evidence itself if present.

An odd characteristic of POJ 2878 was the very large proportion of tasseling which took place in the less-than-year-old secondaries. From the results of our fertilizer experiments, it appears quite possible that this heavy secondary tasseling was induced by a shortage of available nitrogen for normal growth of these secondaries under the single second-season application used in this experiment. The nitrogen content of the secondaries was unfortunately not determined. This tasseling was followed within three months by the dying back and spoiling of a large percentage of the stalks so affected. An interesting fact appeared in July of the second season in 31–1389 and that was the gradual disappearance of small suckers through dying back. They did not enter the crop as millable stalks.

Total Weight of Cane (Fig. 8):
Weight of Cane in Age Sections (Figs. 9 to 13):

The curves for total weights of millable cane for all ages of stalks shown in Fig. 8 are subject to the criticism of being taken from one 20-foot line harvest and while, on the whole, quite representative of conditions in the field, they are subject to the errors of non-replicated plots. This shows up quite definitely in the erratic behavior of H 109 in the September harvest (No. 5) and in this case was due to shading out, *i.e.*, the border effect of the line cut in harvest No. 4 which had "gone down" over No. 5. This one harvest yield should have shown weights equal to, or slightly above, those for 31–1389 and POJ 2878 in the curves.

The entrance of many formerly non-millable second-season secondaries into the millable cane class in 31–1389 and POJ 2878 at this harvest (No. 5) raised the yields of cane greatly, whereas weight increases in H 109 were largely made in the primary class of stalk, thus making the stand in H 109 much more homogeneous as to age and yield characteristics.

In Figs. 9 to 13 are shown the yields from the age-season sections of the primary stalks. They are presented on both the green- and dry-weight bases of calculation.

In the 4-month age section the slow-starting qualities of H 109 are clearly indicated (Figs. 1 and 8). The position of POJ 2878, as the lowest producer in this age group, was due to its smaller, lighter stalk characteristics and possibly reflects the effect of our having limited stalks per line to a common count in all varieties. Also it is illustrative of the fact that elongation rates were less in this variety from an early age.

In the 8-month section H 109 had obtained a foothold and had begun to produce primary stalk weight at higher rates than the other two varieties, a fact not shown by elongation rates or total elongation (Figs. 1 and 2). The weights in this section

FIG. 10

Green Weight Of Cane At Harvest

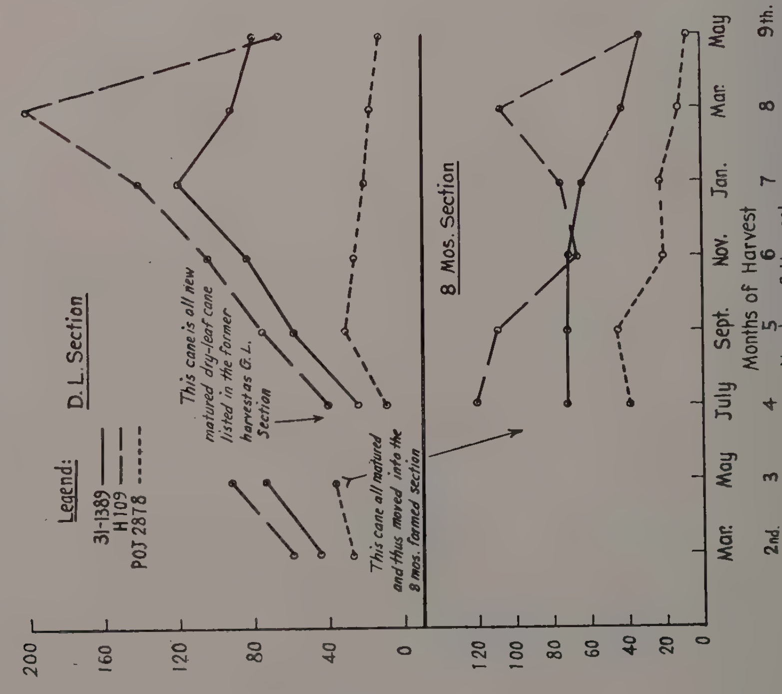
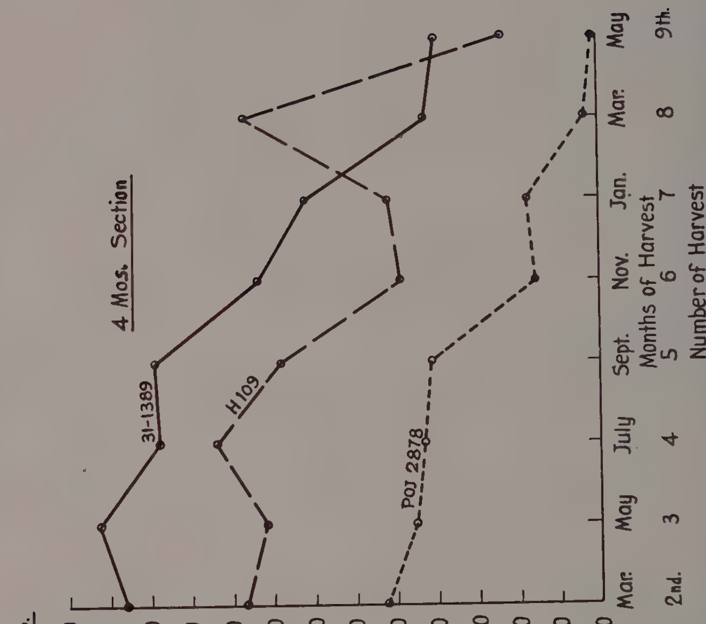


FIG. 11

Green Weight Of Cane At Harvest



are also indicative that the fall temperatures, under which this section was formed, did not inhibit the weight growth of H 109 as seriously as it did the other varieties. These weights appear to indicate also that H 109 possibly has a lower threshold value for growth-temperature relations than have the other two varieties. If so, then the assumed 70° F. base for "day-degrees" calculations may not be fixed and may have a different value for each variety. In the elongation rate and total elongation curves, Figs. 1 and 2, the discrepancy between length growth and weight growth is strongly pointed out by the fact that H 109 did not move into the lead in the elongation measurements until long after this 8-month section was complete and in the dry-leaf stage of growth, although H 109 was definitely in the lead, in weights produced, early in the fall, as will be seen from the data for both dry-leaf, green-leaf, and 8-month sections in Figs. 9 and 10. (Refer to description of the physiological composition of these samples, pages 149 and 151.

The dry-leaf section after the fourth harvest represents the mature cane formed after the completion of the 8-month section and shows the weight increments added from harvest to harvest. In this section total elongation and elongation rates of H 109 and 31–1389 correlate much more closely with cane weights produced at this age than in the former 8-month section just discussed; this is perhaps indicative of a change in H 109 in the relative stalk dimension ratios of mean length to mean diameter (or in density of the stalk).

In the green-leaf section the weights are made up of almost entirely new tissue at each harvest and show the amounts of cane produced under seasonal influences. The close parallelism of this section to the rates of growth curves, Fig. 2, for H 109 and 31–1389 is evident. However, in the case of POJ 2878 the rate-of-growth curve, for the live active primary stalks which are measured, does not correspond to total cane weights in the field, since losses, due to the death of the other primaries, had more than offset the additional growth made by the few remaining healthy stalks in this variety.

The non-millable top section is made up of non-colored, soft, white, top in which elongation of internodes has been only partially completed. This section of cane is the section of stalk which formerly was topped off and discarded when we were able to cut cane by hand. The weights involved in it are not representative of length-growth rates or of rates of weight formation; they do, however, indicate from harvest to harvest the decreases in relative weights and volumes of vegetative material making up the active apex or growing top with increasing age.

The summation of the weights of the non-millable top and green-leaf section at any harvest is the weight translation of the elongation rates shown in Fig. 2.

When we take into consideration the variable behavior of the primary stalks of these varieties, as influenced by age and season, and the simultaneous behavior of the secondary and sucker fractions as depicted in Figs. 4, 5, 6 and 7, the tremendous complexity of sampling a field of cane at any time can be comprehended. Regarding the practical application of sampling for control of fertilization in the field, we have found by experience that with our present varieties and cultivation practices, our fertilizer applications must be applied inside of one year of age (from planting or ratooning). If we control the fertilization applied by crop index figures derived from primary stalk samples within this first-year period, an inspection of Figs. 4,

FIG. 12

Dry Weight Of Cane At Harvest (Lbs.)

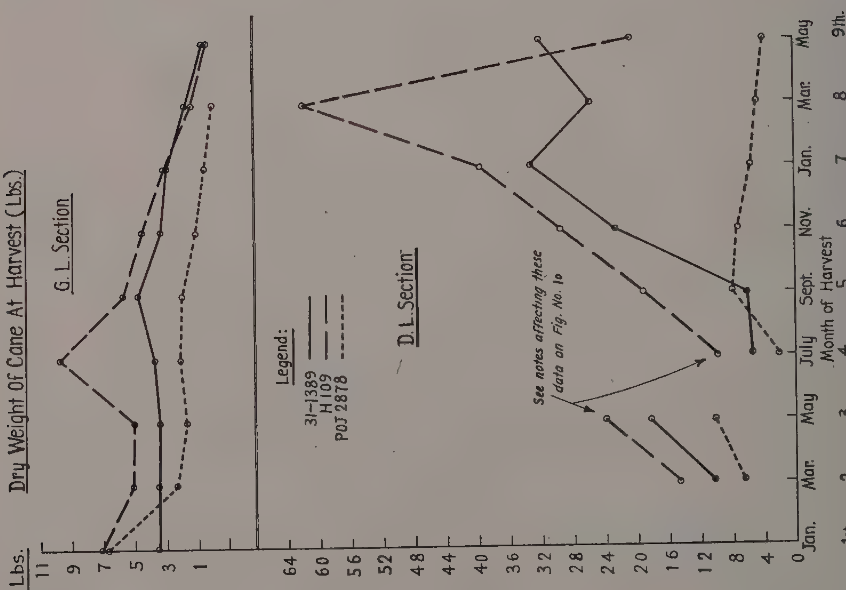
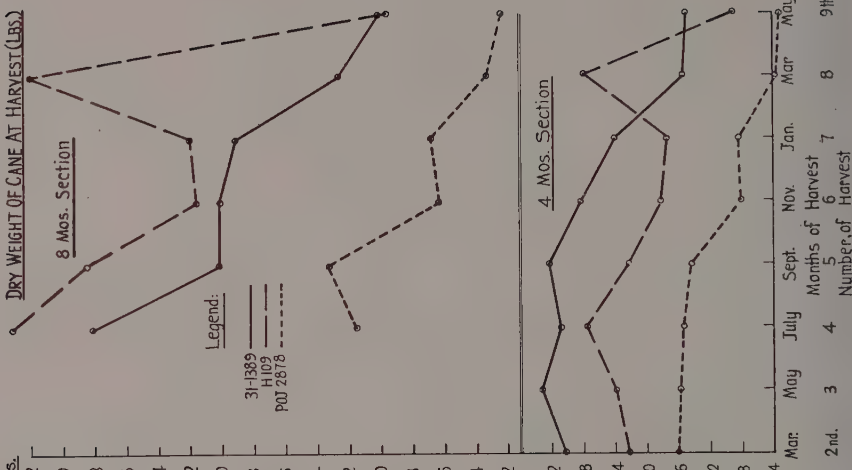


FIG. 13

DRY WEIGHT OF CANE AT HARVEST (LBS.)



5, 6 and 7 will show that the 30 to 60 per cent of the final crop made up of the secondaries, depending on the variety involved, will not only not be represented in our index samples, but will not even be existent in the field, except possibly as less than one-foot suckers. Index figures, based on primary stalks from short crops and on crops of low-tillering varieties (where only primary stalks will be involved in the stand) may possibly be used satisfactorily for control of fertilization. However, the shortage of manpower, high costs of cultivation of short crops, and other economic factors have practically necessitated that most of our plantations adopt long-crop practices, and nearly all of our better recent cane varieties are vigorous-growing, heavy secondary-stooling types in which homogeneous stands do not exist except at a very early age.

The factors effective in producing secondary growth, and the physiological behavior of this secondary growth, have not been worked out. We are cognizant that light incidence, timing of nitrogen fertilization, initial stand density, temperature and other variables have a bearing on the number of secondaries produced. The subject has not been studied quantitatively or qualitatively, however, to the extent where we are able to predict varietal conduct of these secondary stalks.

Hence until a complete study has been made of a variety and we are able to predict more accurately exactly what the yield of secondary and other stalks is most likely to be under any set of growth conditions and fertilizer treatments, the selection of a so-called "representative" sample, taken within the first year of life of a crop, cannot reliably approximate representation of what the crop will be twelve, ten or even six months in the future. The analysis of such a sample and the interpretation of the analytical data will offer little help in the guidance of fertilization of stalks which were non-existant at the time of sampling.

Mortality (Fig. 5):

Death of first-order stalks in all varieties had set in before the spring of the second year. Mortality rates which were greatest for POJ 2878 were followed roughly in decreasing order by 31–1389 and H 109. Some of these stalks died due to tasseling in the first fall, some due to tops being broken by wind, and some were broken or split at "going-down" time in the first winter; others, parallel to our findings in the fertilizer test, died for no readily apparent reason.

In secondary stalks, dying out of weak shoots through overcrowding at secondary closing-in time occurred in all varieties. This factor, however, was more operative in POJ 2878, as it initially had many more secondaries than the other two varieties. Tasseling in this variety, as mentioned before, was heavy in the second fall and the affected sticks died back rapidly soon after. In 31–1389 there were very few secondaries that tasseled in the second fall.

pH of Cuba Mill Expressed Juice (Figs. 14 and 15):

Juice acidity of the three varieties, as determined by the Beckman pH meter, shows not only the same general levels of pH as found in former work (2, 3), but also the same seasonal and age trends in the age sections studied.

The higher acidity of the non-millable top sections is probably ascribed to the increase in concentrations of organic acids concomitant with vegetative activity. In

FIG. 14

pH Of Expressed Juice

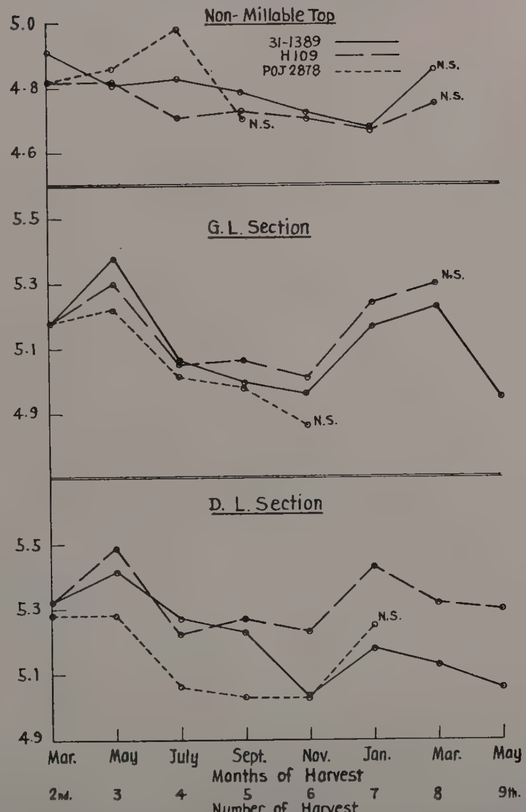
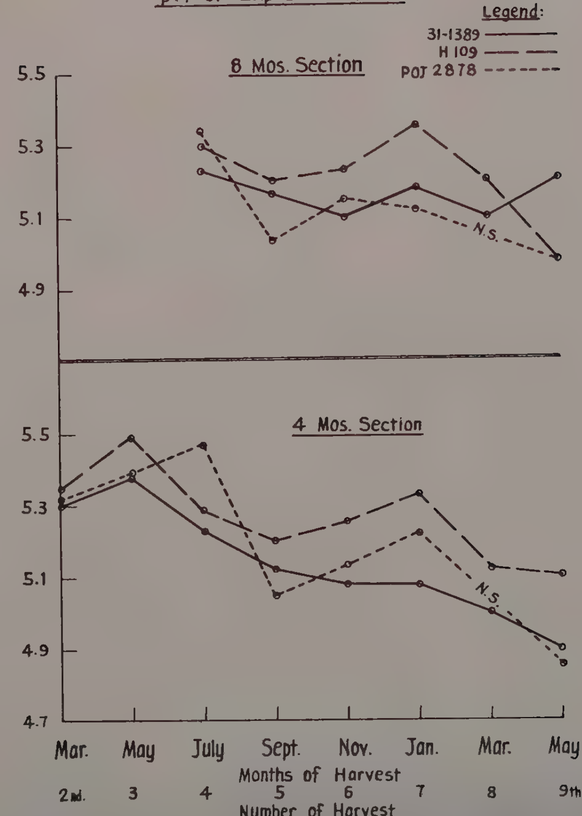


FIG. 15

pH Of Expressed Juice



the green-leaf sections lower acidity is found, probably due to diluting effects attendant to further cell development, such as reduction in pectic acid, tannic acid derivatives, and condensation of amino acids to proteins. One must remember also that in the green-leaf stage of development, anabolic processes far out value the catabolic, and that organic acids formed by respiration in the cells have not had time to accumulate as they will have done when this tissue becomes mature cane (as in the 4-month section).

Identification of the various acids in the sugar cane plant has not been made. This field could quite profitably be followed since a study of our former experiments will show that increased age is accompanied by decreases in pH in mature cane until a pH of 4.8 to 4.9 is reached, at which time degeneration of the crop sets in. We feel that this degeneration is probably due in a large part to increased destructive activity of invertase (or other enzymes) at or about this pH.

Microchemical pH range indicator studies on tissue cut from age sections having juice acidities of 4.8 to 4.9 showed that there were interfaces in the protoplasm of some parenchymous (storage) cells with pH's of 3.2.

A factor which we recognize as being active in the seasonal pH variations is the change in water content of the plant parts with possibly no quantitative change in total acidic material present. In a prior report (3, p. 171, second paragraph), we were led to doubt the validity of conductivity measurements on sugar cane saps when interpreted as a measure of the ash constituents (usual physico-chemical interpretation), and we suggested that more likely they were a measure of the acidic radicals in the saps. A comparison of pH and conductivity curves in this experiment will, we feel, further bear out our contentions in the matter, although the relationship is not perfect.

It will be noted that at the seasonal periods of higher acidity and conductivity of the saps of the various older sections, there was an accompanying increase in moisture. From these conditions it may be inferred that there was a real increase in the acidic contents of the expressed saps, a higher ionization of acidic materials, or a change in the chemical composition of the acidic materials themselves.

While our general statements still hold true, in the latter part of the life of the older age sections of the stalk some other factor or factors are operative for each variety, for the relative conductivity curve positions (Figs. 16 and 17) found in POJ 2878 and 31–1389 do not correspond to those of the pH determination. While purely speculative, since we did not run ash analyses on this tissue, we feel that the results are possibly due to small variable salt concentrations in the older tissues.

The pH of juice expressed in the Cuba mill was, we realized, the result obtained from a composite of true solutions, suspensions, and colloidal sols and, as such, represented no one thing. Attempts to find in living tissue, as mentioned above and in a former paper (3, p. 174) just what the pH of vacuolar saps were, by means of range indicator dyes, met with no success through protoplasmic interface interference with dye penetration. We still do not know at what acidity value sugar is held in storage cells. All indications are that the vacuolar saps of storage cells are acid but one must not construe pH of expressed juice to be identical therewith. Water from the vascular system, salts in transit, liquids from cell walls and protoplasm,

FIG. 16

Electrical Conductivity Of Expressed Juice In Mhos.

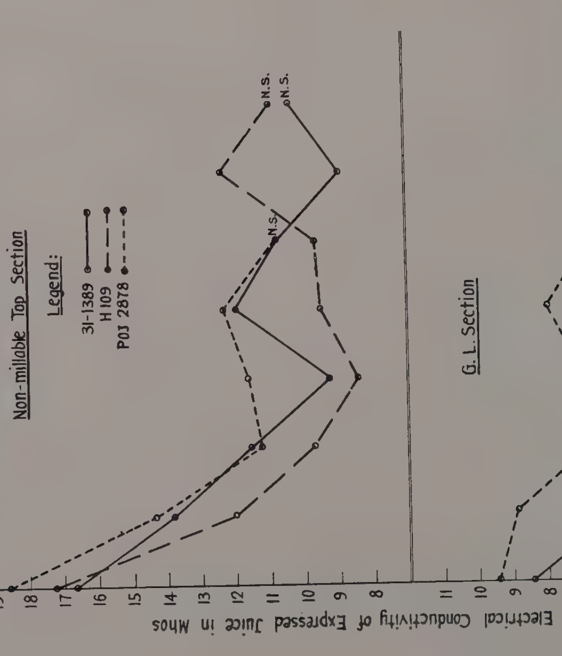
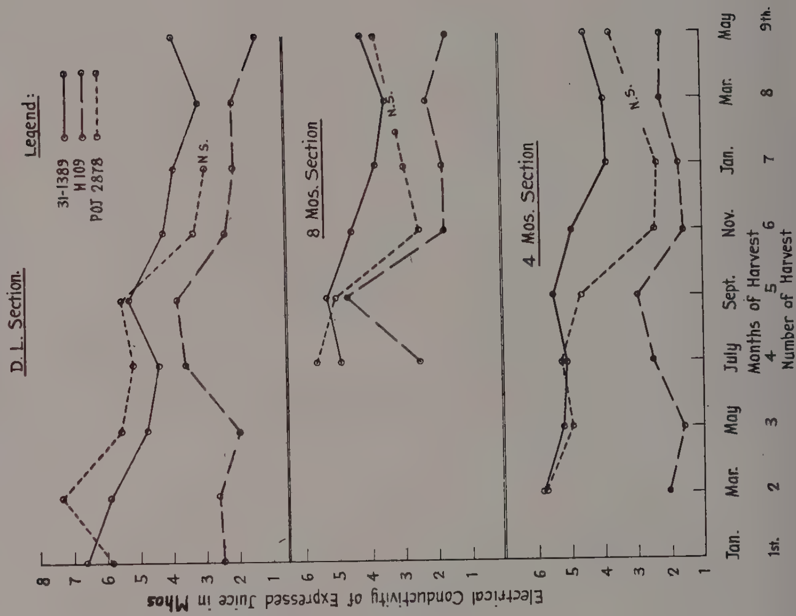


FIG. 17

Electrical Conductivity Of Expressed Juice



all are mixed indiscriminately. To the sugar boiler, who is liming for clarification, the figures are valuable, but they leave much to be desired by the plant physiologist.

From a study of Figs. 14 and 15 it becomes immediately apparent that H 109 has a higher pH (or less acidity) of juice than the other two varieties, except in the non-millable top section. This condition also seems to be borne out by the conductivity of juice (Figs. 16 and 17), for therein this variety shows considerably less carrying power for electrical charges than do the other two varieties.

At this time we can offer only a presumption as an explanation of why these acidity differences occur or what they are actuated by, since we did not identify the acidic materials.

On the thesis of accumulation of organic acids with increases in physiological age and decreases in physiological activity of the cells, we might expect some such result since H 109 maintained its vigor in primary stalks longer than did the other varieties. However, we are not satisfied that this is the real reason for difference, for we observed at each line harvest that both POJ 2878 and 31–1389 stalks, when cut and exposed to the air, seemed to form brown oxidation products much faster than did H 109 cut sections. This browning of cut surfaces has been ascribed to presence of tannic acid and/or tannin derivatives. Since no explanation of how or why tannins occur in plants has been made by plant physiologists, although all kinds of unproved theories have been offered, we will in passing merely note their presence as varietal differences.

While not having a direct bearing on this test, we would like to direct attention at this time to the fact that on several occasions we have found levo-rotatory sugars in excess of dextro-rotatory in the reducing sugar fractions in the expressed juices of cane. This condition occurred in every case during very warm summer weather and in rapid elongation or cellulosic tissue-formation periods. While purely hypothetical, we felt that their presence might be indicative that in the metabolism of the cane cell, glucose was preferentially used to form cellulosic materials and levulose used for furnishing the cell energy. If this were a fact, we would expect to find glycollic acid and a-hydroxy-butyric acid formed during the breakdown of the levulose. To date we have been unable to find methods to isolate these acids from mixtures in the plant and so are unable to report any progress. Conant (1) reports the presence of glycollic acids in sugar cane, but we have been unable to find his source material for reference. Due to apparently less "fiber" being formed in both 31–1389 and POJ 2878 than in H 109, it may be possible that more carbohydrate-derived acids, from the reducing sugars used in cell metabolism, are left behind in these two canes than in H 109. We would like to have these points watched for by other workers as they may be able to establish relationships we can only hypothesize.

Conductivity of Juice (Figs. 16 and 17):

We ran conductivity measurements of expressed juice because we originally had accepted the idea that conductivity of saps measured soluble inorganic ash constituents in the plant. Today we are more than dubious of this idea. The data accumulated are, we now feel, of little value in themselves, but when studied in relation to pH and moisture data, they have been of help in aiding us to interpret the latter a bit more intelligently. We present the plotted results herewith but wish to make no

FIG. 18

Gms. H_2O Per Gm. Of. D. M.

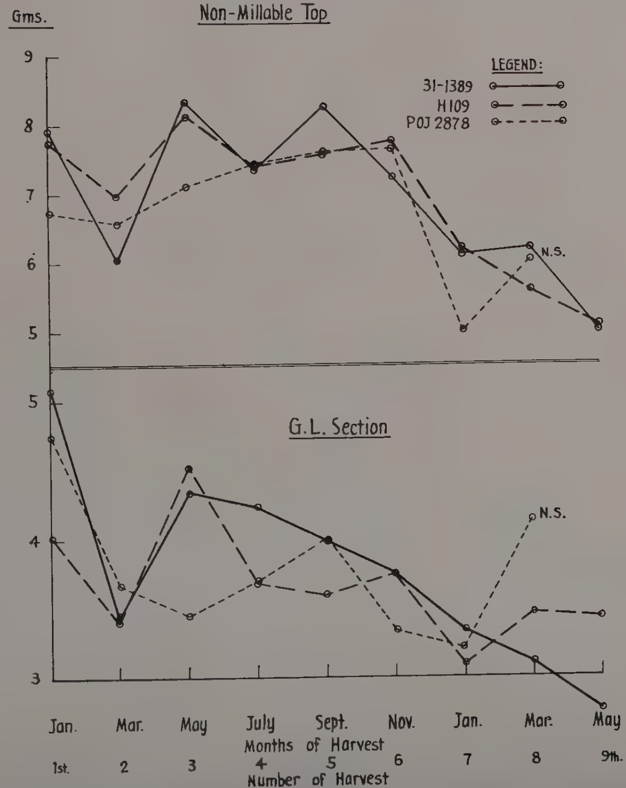
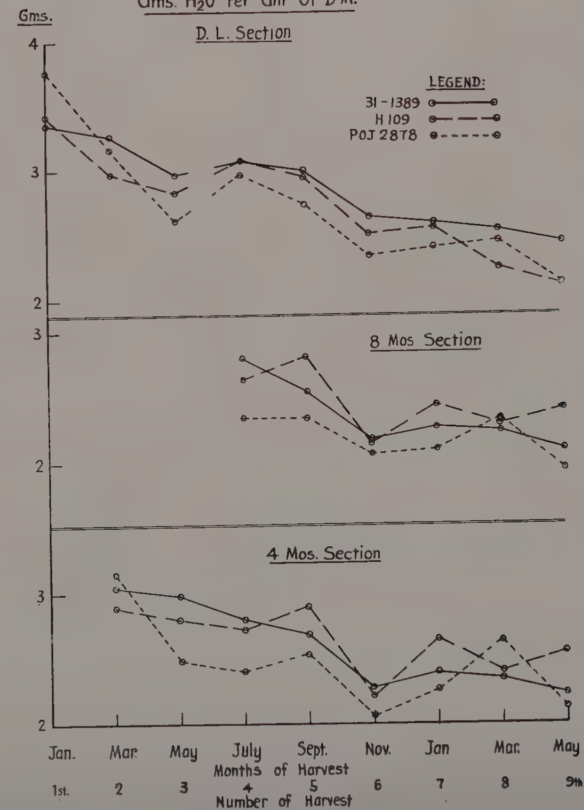


FIG 19

Gms. H_2O Per Gm Of D M.



further evaluation of them since they are approximately the inverse of the curves for pH just discussed.

Moisture Content of Cane (Figs. 18 and 19):

The water content of the canes involved in this study is expressed in two ways, one as grams of water associated with one gram of dry matter, and the other as per cent of dry matter in green matter.

Of primary interest is the fact that POJ 2878 rather consistently has a lower water content than the other two varieties at all chronological ages studied and in all age classes of cane. In general no such difference appears to exist between H 109 and 31–1389, harvest by harvest: however, after careful study we do feel that while there is no great final difference in inherent moisture levels of any set of age-section tissues, there are different moisture levels for each variety which are determined by the magnitude of seasonal vegetative activity.

The question may arise in the reader's mind as to why the hydration curves, especially for H 109 and 31–1389, cross and recross in any age section as they do. We offer no apology for we know the determinations were mechanically correct, but we do offer the explanation, for the sake of clearness that many factors affect such samples. One factor is the normal variability which may be expected when dealing with as nearly identical biological material as can be chosen. As most cane men know, this error can hardly be reduced below $\pm$ 2 to 3 per cent in field-grown cane even under the best of conditions.

As is recognized by many biochemists, absolute water content figures from living tissue are impossible of attainment, although highly useful relative measurements are easy to secure. The higher the colloid content of tissue, the more inaccurate become the relative moisture determinations by oven, vacuum oven, evaporation, etc. Our methods were standardized throughout this experiment and constant weights of samples were attained for our conditions of oven drying at 85° C. in every case.

Another variable was traced to actual percentage differences anatomically in the tissues making up the samples. With nodal and internodal tissue mixed in the age-section samples, there were considerable differences introduced due to the difference in length of internodal tissue (and volume) as compared with nodal material. An experiment to follow this one has been designed to take into consideration this anatomical factor and our findings will be reported at a later date. Great varietal difference in length of internode exists as all cane operators have observed. In our former work, and from other investigator's data in the files of the Experiment Station on rates of leaf appearance, we find that rates of node formation are relatively constant, whereas the length of tissue laid down between the nodes is dependent upon growth conditions existent at the time the internode developed.

The last and most confusing factor in moisture determinations on cane is our inability to evaluate water which is not strictly speaking involved in the life processes of the cell. In this category falls the water in the open vascular system of the plant. The amount of this water varies largely with available soil moisture, will drain freely from cut stalks or will squirt out in fine streams as the cane first enters the crusher in the mill. It appears to be present much in excess of the needs of the plant for cell turgidity or transpiration. Technically speaking it will interfere with accurate, relative moisture determinations unless irrigation and rainfall are posi-

FIG. 20

Percentage Reducing Sugars In Juice

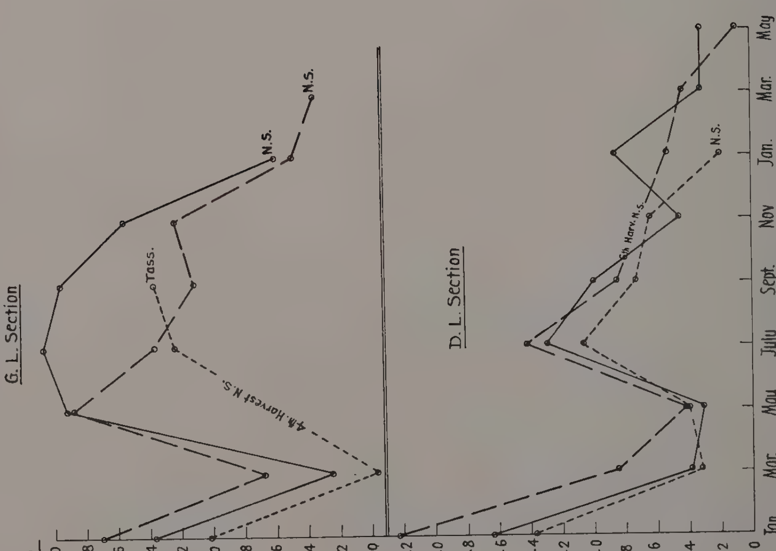
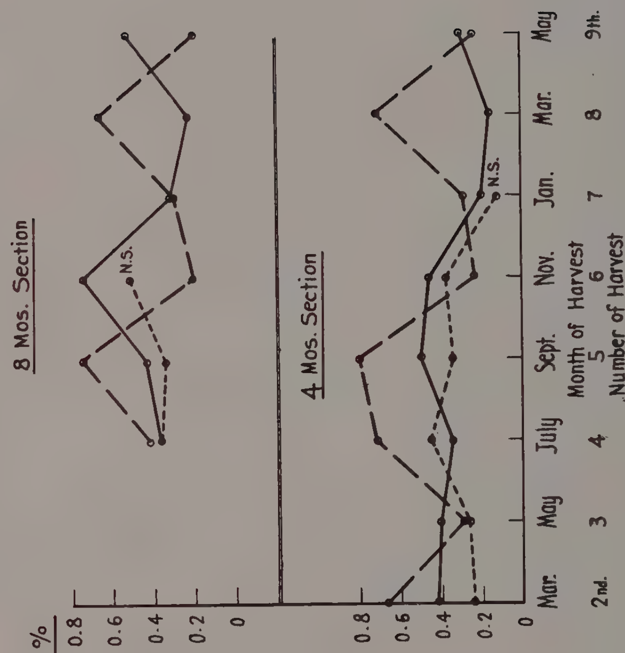


FIG. 21

Percentage Reducing Sugars In Juice



tively controlled. We tried to avoid this type of moisture variation by keeping the cane lines thoroughly irrigated at all times and the vascular system flooded. The rapid increase in dry matter of the top section at the seventh harvest is directly attributable to the increase in volume of nodal material in the samples due to season and age interferences with elongation of internodes.

Reducing Sugars (Figs. 20 to 24):

Reducing sugars were determined on the dry-weight basis and on Cuba mill expressed juice. While trends due to season, age, and vegetative activity are comparable in the various curves, a certain degree of nonconformity exists in the position of the varieties at various harvests. At first glance these nonconformities appeared to be inaccuracies in analysis and we were almost led into blaming extraction variations in the Cuba mill. The regularity of the reducing sugars on dry-weight basis in the older parts of the stalk for the sixth and seventh harvests would seem to indicate such inaccuracies existed. A careful study of the sucrose figures both in juice and on dry-weight basis, and of moisture, showed that the sucrose had suffered a decrease, thereby reducing the base of absolute amounts of dry matter used in percentage calculations. Thus for the reducing sugars on dry-weight basis to remain at an approximately constant percentage figure (as they did), they too must have suffered a reduction in absolute amount, as was indicated in the juice analysis figures.

Here again is proof of the seasonal ebb and flow in sugar content of older tissues for, had the indicated reduction in both sucrose and reducing sugars been used by the plant for formation of only fibrous cellulosic materials, the reducing sugars on a dry-weight basis would have shown a depression. However one analyzes the data, either loss through translocation or catabolism was operative in the sixth and seventh harvests in H 109. Since tillering was not taking place at this season and age of crop, metabolic losses are indicated.

Once again we feel we have evidence that the sugars of the cane plant are not "static" once they have been laid down, but are dynamic and changeable under the influence of season, weather, and age.

The three varieties all show trends due to season and age similar to those found in our former experiments. H 109 due to its vegetative vigor in the second season has a higher reducing sugar content in the older age sections, this, however, does not appear to be much higher at the last harvest than the other two. In the curves for reducing sugars on a dry-weight basis, it will be noted that both POJ 2878 and 31–1389 in the four- and eight-month sections reached a minimum level at the fifth harvest (September), while top, green-leaf and dry-leaf sections were still immature in this respect. Since the most rapid primary cane formation was made in the first year in these varieties and falls into the two categories which were more mature in quality, it appears that they could be harvested with fair results at 16 months of age and again at about 22 to 24 months when the entire surviving stalk stands have reached maturity throughout.

POJ 2878 first-order stalks play proportionately so small a part in the crop *after 12 months* that too great value should not be placed on these analytical results in judging optimum harvest periods. However, the data for 31–1389 and H 109 are pertinent, as larger proportions of the crop are first-order stalks.

FIG. 22

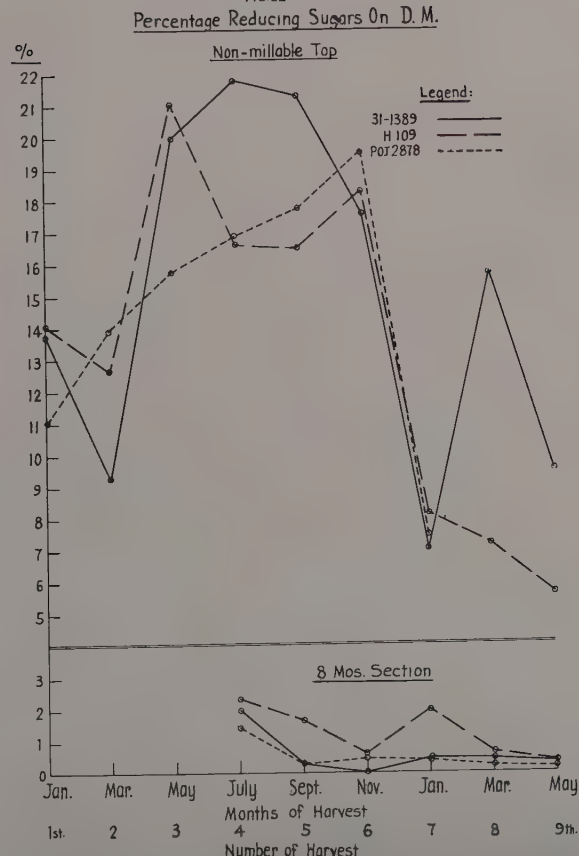
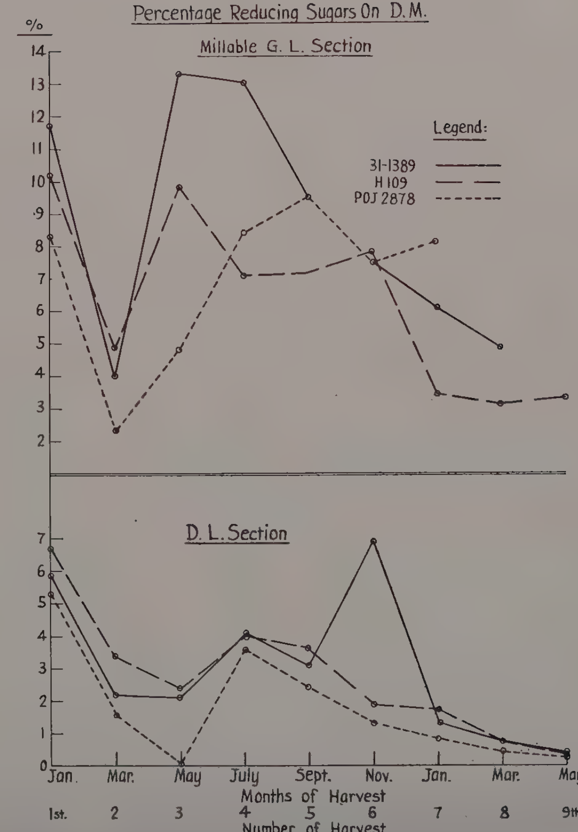

Percentage Reducing Sugars On D.M.
Non-millable Top
%
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
3
2
1
0
Legend:
31-1389
H 109
POJ 2878
8 Mos. Section
Jan.
Mar.
May
July
Sept.
Nov.
Jan.
Mar.
May
Months of Harvest
1st.
2
3
4
5
6
7
8
9th.
Number of Harvest

FIG. 23


Percentage Reducing Sugars On D.M.
Millable G. L. Section
%
14
13
12
11
10
9
8
7
6
5
4
3
2
Legend:
31-1389
H 109
POJ 2878
D. L. Section
7
6
5
4
3
2
1
0
Jan.
Mar.
May
July
Sept.
Nov.
Jan.
Mar.
May
Months of Harvest
1st.
2
3
4
5
6
7
8
9th.
Number of Harvest

Once again, as in our former work, the increases and decreases in percentage of total sugars, due to seasonal effects, are operative; the gains and losses in sucrose are greater by several times than the corresponding contemporary variations in reducing sugars; and the water content of the tissue varies with the reducing sugar content. However, somewhat contrary to our former experience and affecting all three of the varieties alike, we find sucrose content depressed at the same time the water content was depressed. This occurred during the fall harvests of the second year (November and January). The only explanation presenting itself for this condition is that considerable non-sugar dry matter was formed under the fall weather stimulus and was built at the temporary expense of stored sugars. The deficits encountered were apparently made up in the spring months following. No such condition was encountered in the contemporary fertilizer experiment adjacent, leaving us at a loss to explain this satisfactorily.

Sucrose (Figs. 25 to 29):

The sucrose is expressed in two ways, as were the reducing sugars, on the dry-weight basis and on Cuba mill expressed juice. Comparison of the curves for the two bases of expression show considerable dissimilarity, not only in position of the varieties at each harvest but in the general seasonal trends as well.

Per cent of sucrose in the juice is highest in POJ 2878 in the two mature-age sections (four- and eight-month) after the canes were one year of age, and on the dry-weight basis a similar condition seems to obtain. However, on the dry-weight basis of the dry-leaf, green-leaf, and non-millable top sections, POJ 2878 is lowest in sucrose content (after one year of age). This apparently contradictory state of affairs is due to the reduced water content of the tissues making up these second-season sections. The growth rates of POJ 2878 during the formation of these sections were low and the tissues had high nodal percentages, with accompanying higher fiber content of dry matter. H 109 during the same period shows the highest sucrose percentage on a dry-weight basis, due to just the opposite set of conditions holding. It was forming cane at a good rate, proportions of node to internode were lower than 31–1389 or POJ 2878, relative moisture content was higher, and when the interactions of all these factors are considered, the juice analyses results are about what one should expect.

In all varieties there is evidence of the accumulation of sucrose with age in all parts of the plant, a condition which we have experienced in every experiment which we have carried out thus far. We have ascribed this behavior to several conditions which are induced in the cell by age: (*a*) A loss of nitrogenous colloids from the interior of the cell, as indicated by reduced total nitrogen content; (*b*) a reduction in total water-holding capacity of the cell colloids through their partial removal, as indicated by moisture data; and (*c*) a general though small increase in vacuolar volume allowing increased storage space in a given sized cell. We feel certain that we have observed this latter condition microscopically, but we admit the latter condition is largely presumptive since water content will affect colloidal volumes to a tremendous extent—so much so that simple visual observation is of little or no value in judging colloid content or properties.

Another condition, theoretically possible, is that with the reduction of nitrogen and the accompanying gradual reduction in content of reducing sugars (to a basal

FIG. 24

Percentage Reducing Sugars D.M.

4 Months Section

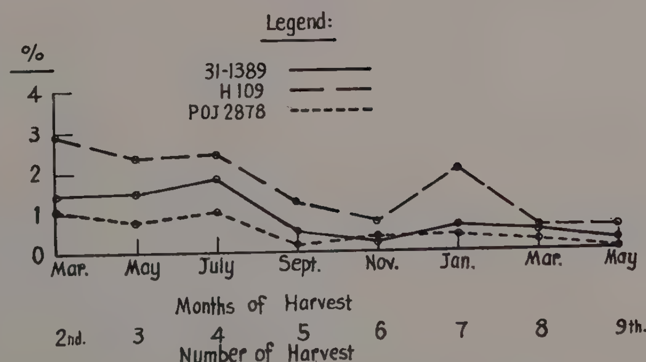
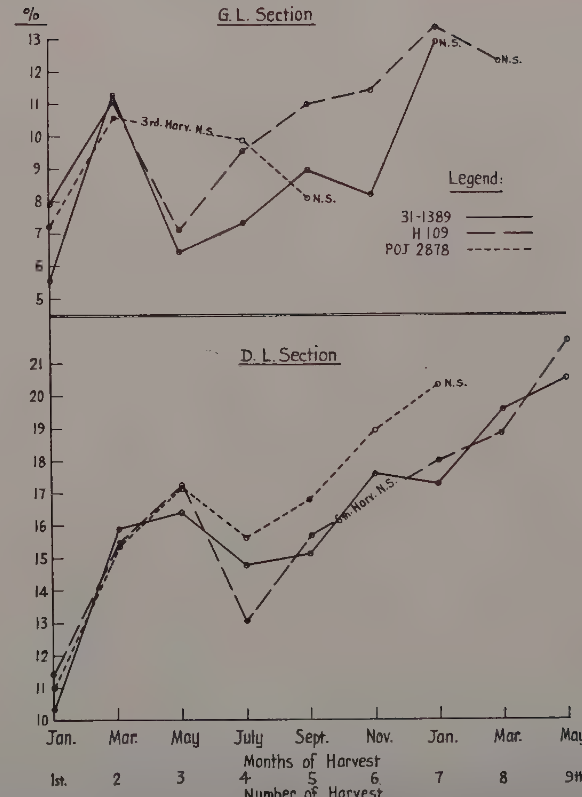


FIG. 25

Percentage Sucrose In Juice



metabolic level of .6 to 1.0 per cent on the dry-weight basis), the osmotic pressure in the cell, partially maintained by the presence of these simple sugars, is reduced and the relative percentages of sucrose can increase. From the theoretical point of view, and from measurements of osmotic pressure on sucrose and glucose solutions (6, 7), the removal of 180 units by weight of glucose from a cell would allow its replacement by 342 units by weight of sucrose without disturbing the osmotic pressure in a cell.

In this test, as in our prior work, we ran depression of the freezing point on Cuba mill juices to determine osmotic pressures of each age classification of cane. Unfortunately this method does not yield results that are identical to the osmotic pressure in the vacuole of an undisturbed, active, living cell and added errors are encountered in that the sap extraction is not 100 per cent in the Cuba mill, vascular water is mixed with the expressed cell saps and the osmotic pressures tend to be probably too low and, possibly, not even comparable between varieties—due to different varietal water content of tissues.

In our other experiments, as well as this one, it was found that when sucrose variations occurred, the contemporary opposite increases or decreases in reducing sugars, expressed either as percentage or absolute amounts, never balanced the sucrose variations. A relatively stable osmotic pressure balance in the cell maintained by variable, interacting, molar concentrations of monosaccharides and disaccharides could readily explain a considerable part of the weight and percentage variations we have encountered. This statement should not be taken to mean, however, that catabolic losses are not the important factors for the unbalance, it merely points to a possible physical mechanism of sucrose increase or decrease in the plant which will not allow direct correlation of percentage figures for sucrose and the reducing sugars in a cell of fixed volume. For direct correlation, molar concentrations of all the solutes would have to be used.

Inspection of sucrose on the dry-weight basis curves for the non-millable top and green-leaf sections shows that physiologically these two sections differ only in degree at any harvest. The varying sugar concentrations noted in these two sections at each harvest were determined on new, fresh-formed material at each harvest and thus represent the resultant of the two forces affecting sucrose supply, photosynthesis and growth at the time of harvest.

In the dry-leaf section the data represent, for the first and second harvests, increments of cane material which later makes up the four-month section. In the third and fourth harvests, the data show the conditions present in cane material which later goes to make up the eight-month section. After the fourth harvest, the data for dry-leaf sections represent the mean figures for a section of cane stalk to which has been added new material at each harvest made up of fractions coming into the more mature category during the previous two-month period. It might be almost regarded as a sliding average.

As has been described before, the four- and eight-month sections were fixed sections of stalk which one could study as units physically invariable (other than for biological sample variation) except from the internal physiological changes (which we were attempting to measure). To trace the behavior of sucrose in the juice of a section of stalk from the green-leaf stage to maturity, attention is called to Figs.

FIG. 26

Percentage Sucrose In Juice

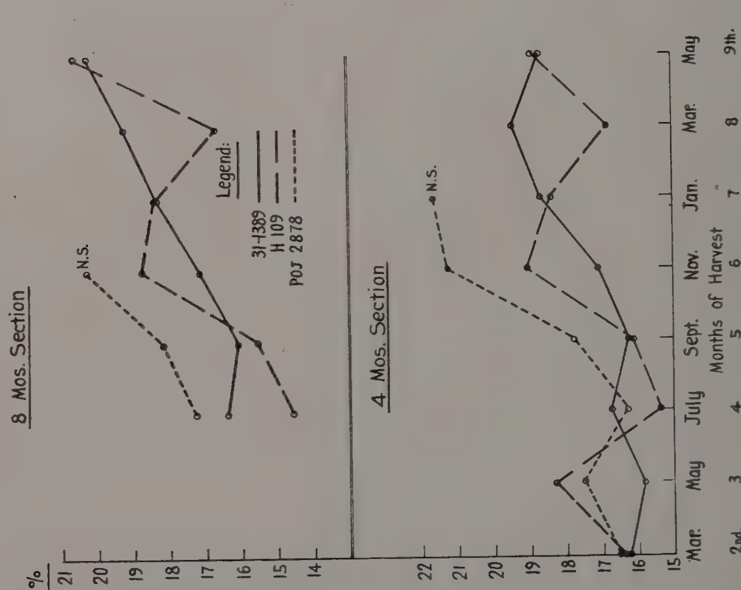
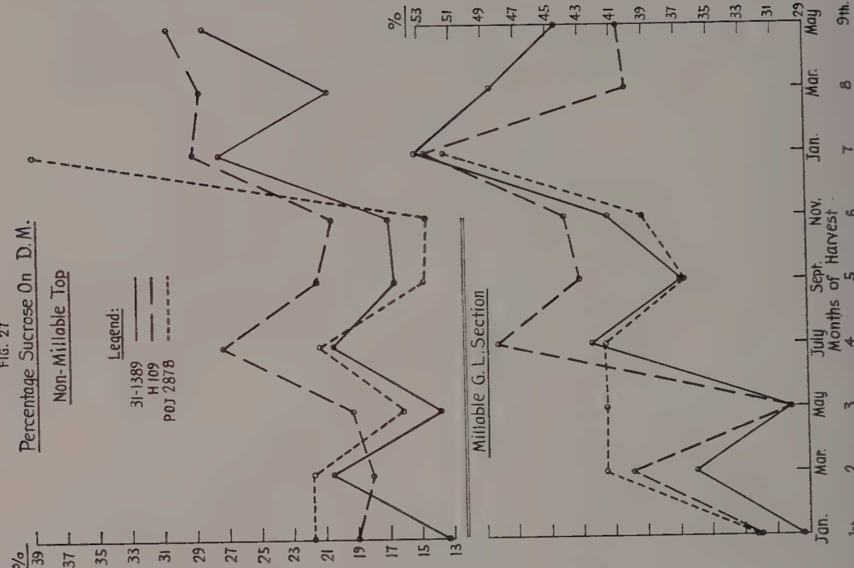


FIG. 27

Percentage Sucrose On D.M.



25 and 27, harvest Nos. 1 and 2 in the green-leaf section, and harvest Nos. 2 and 3 in the dry-leaf section; then to Figs. 26 and 28, for the eight-month section from harvest Nos. 4 to 9. The cane in the green-leaf stage at the first harvest is found two months later at harvest No. 2 in the dry-leaf stage. Two more months of fresh growth is shown in harvest No. 2, green-leaf stage, and this is found at the third harvest in the dry-leaf stage. Again the cane at the third harvest in the green-leaf stage is found in the dry-leaf stage at the fourth harvest, and so forth.

Thus for the cane making up the fixed eight-month section, covering a period of initiation and of growth from November to March in the top and green-leaf stages, and from March until the end of June in the dry-leaf stage, and from then on to 24 months in the eight-month group, the sucrose percentage in juice increased roughly from five to eleven per cent in the green-leaf group, from about eleven to fifteen per cent in the dry-leaf stage, and from fifteen to nineteen per cent in the eight-month classification.

Turning to the four-month section, while it was in the dry-leaf stage of development, the sucrose in juice increased some five per cent. When this cane became a fixed section at the second harvest, little or no changes occurred in the sucrose in juice for some six months or until the fifth harvest, when an increase of some three per cent occurred in all varieties.

There is apparently no conclusion possible other than that increases occur very definitely in sucrose concentrations in juices even after the cane has reached the dry-leaf stage of maturity. It must be remembered that the juices analyzed were derived from all the cane in a 20-foot line after eight stalks were selected for analysis on a dry-weight basis and, for this reason, give fairly smooth accurate curves.

When we turn to the curves for sucrose on dry matter in eight selected first-order stalks, we find the same long-time trends apparent but they are subject to large harvest-by-harvest variations. These variations show up in the percentage of dry matter in green matter, and in the moisture curves. They indicate that the variation in sugars-to-dry-matter ratios, encountered in the same age, first-order stalks where small samples are used, may be subject to error. Properly replicated plot tests are naturally the solution to such variations. However, it was impossible for us to do the work entailed in making the large number of determinations of various kinds on more than one set of plots. As many of these determinations in this experiment had never been run before on sugar cane, we chose to run them on one-plot samples rather than have less information of a more statistically accurate nature, especially since this was a preliminary study.

Nitrogen Content of the Cane (Figs. 30 to 35):

Determinations of total nitrogen were run on all age sections of primary stalks and α-amino nitrogen determinations were run on Cuba mill expressed juices from the same age sections by Van Slyke's method.

All varieties exhibited quite similar seasonal variations in total nitrogen content, although there seemed to be an influence from varietal characteristics also. A study of the curves for the first and second harvests points to the fact that prior to our first harvest in the first-season-formed cane material, POJ 2878 had a higher nitrogen content than either of its competitors, a condition which was reversed in the material formed in the second season. A reduction in the nitrogen percentage in the first-

FIG. 28

Percentage Sucrose On D.M.

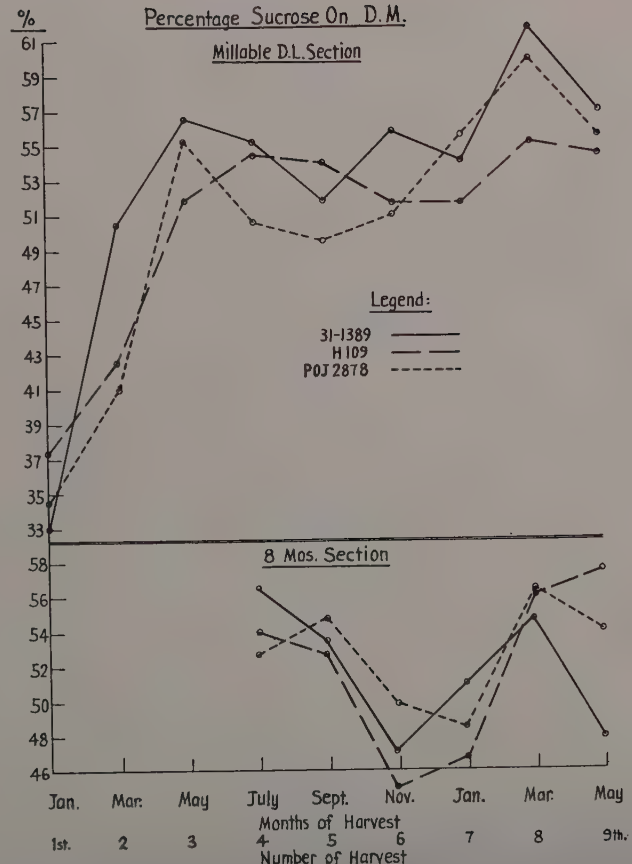
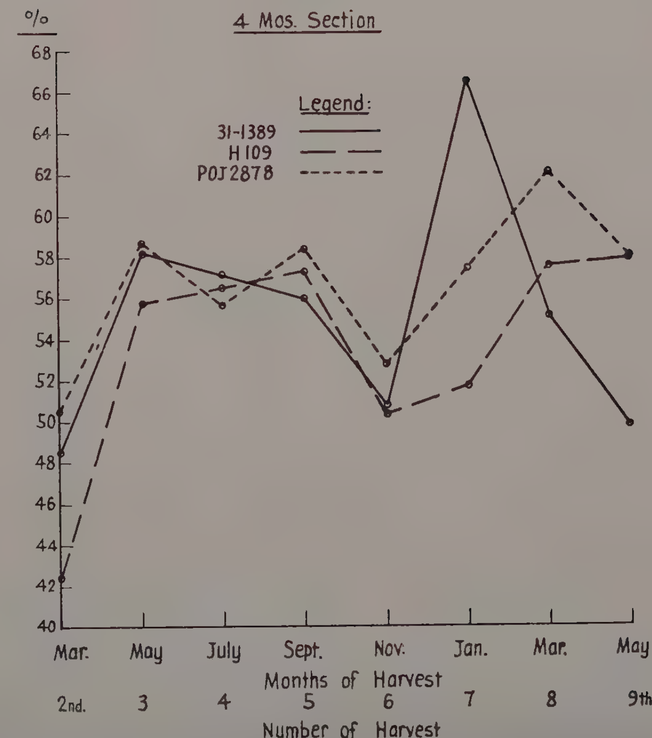


FIG. 29

Percentage Sucrose On D.M.



season-formed material appears in the second year, in fact, to a level below that in comparable stalks of H 109 and 31–1389. This reduction in the second season may have been caused by translocation to secondary stalks, which were then just in the boom stage of growth, or by nitrogen elimination through catabolism or through leaf abscission from the primary stalks, conditions which are controlled by physiological age of the variety. A comparison of the curves for total nitrogen and α-amino nitrogen in the four-month section at the fourth harvest shows that while total nitrogen in POJ 2878 is relatively low, the amino acids in the juice are high. This high percentage in the lower stalk is not followed by a rise in either the top or green-leaf sections in either total nitrogen or α-amino acids. H 109 in the same period does not show any changes in level in either total or α-amino acids. When we remember the relatively low tillering of secondaries in H 109 as compared with POJ 2878, the indications are that we have fair evidence of translocation of α-amino acid forms from the lower parts of the POJ 2878 primary stalks to the secondary stalks.

It is interesting to note the lack of parallelism of curves for all varieties in the green-leaf section when total and α-amino nitrogen are compared. A comparison of total nitrogen curves in this experiment and in our formerly reported nitrogen experiments shows that the total nitrogen figures in this experiment are of the same magnitude and trend. However, the amino nitrogen curves for the two experiments bear no resemblance to each other in the behavior of the top and green-leaf sections in the two tests. A point worth studying is the in general lower total nitrogen percentage of POJ 2878 for all sections in the second year, whereas this cane had by far the highest concentration of free α-amino acids at this period. We feel this a reflection of the physiological age of the primary stalks. Not only was there less nitrogen in all forms in POJ 2878 but there appeared to be less of that actually present, involved in cell metabolism in protein or protoplasmic form (in the second season). We feel this condition was probably reversed in the first season when this cane was making rapid growth. Both H 109 and 31–1389 were vegetatively active in the second season in the primary stalks and carried higher total nitrogen and less free amino acids than POJ 2878.

Nitrogen studies of plants are today in a highly confused state, largely due to lack of methods for either physical or chemical separation of the nitrogen fractions found in the plant into physiological-activity classifications.

From work reported previously (3, p. 173), it appears that there is considerable ammoniacal nitrogen absorbed/adsorbed on or in cell colloids. No nitrate or nitrite nitrogen forms have been found either by microchemical or analytical work in normal field-grown canes in Hawaii. As a matter of fact, chemically speaking, we would be surprised if they did occur in the presence of such large concentrations of reducing carbohydrates as cane normally carries.

As the situation is today, total nitrogen content of tissue is readily determined but of what types of nitrogen compounds that total is made up, little is known. We perforce must attempt to correlate total nitrogen with the various vegetative responses found with results which are not too pleasing in many cases.

Could we but integrate nitrogen into functional fractions in the plant, we would be much closer to a solution of our problems. Quantitive studies of protein (or protoplasmic material), of polypeptide and amino acid translocation forms, and of am-

FIG. 30
Milligrams Amino Nitrogen In 100 cc. Of Juice

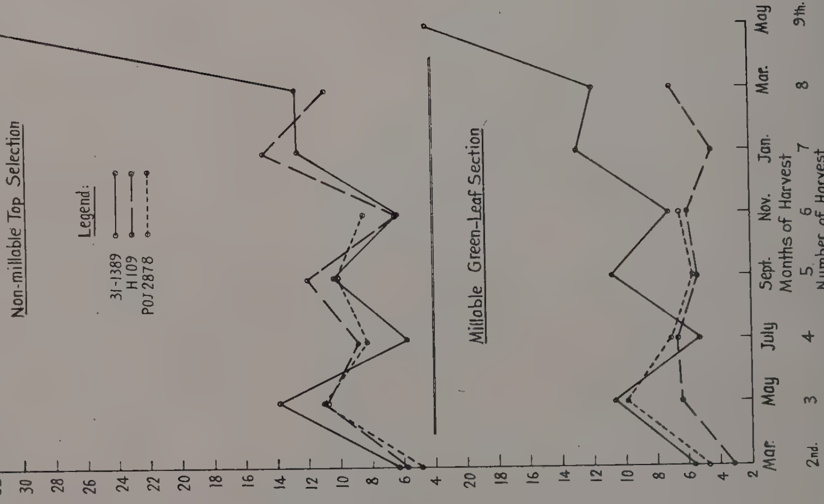
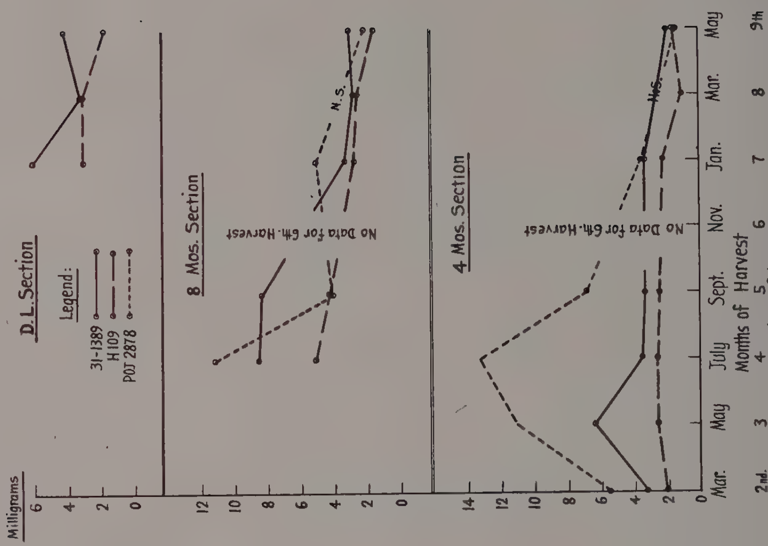


FIG. 31
Milligrams Of Amino Nitrogen In 100 cc. Of Juice



moniacal and inorganic forms adsorbed on cell colloids, would be of untold value when correlated with field data on growth rates, weights, and other determinations.

Under the heading of character and rate of elongation, mention was made of the fact that elongation rates were greatest in May even though peak temperatures and longest hours of daylight were experienced some months later. The highest mean temperatures occur at Makiki in late August and September and the longest daylight hours fall in July, so that the peak rate of growth experienced, with gradual subsidence during the summer months thereafter, is not a reflection of shortage of solar energy, but is interpreted as the effect of a nitrogen application in the preceding March followed by a gradually increasing shortage of this plant nutrient in later summer. There is a report by Dr. U. K. Das and the writer (5, p. 37) on an experiment in which fertilization was carried out at regular two-month intervals, during the first winter and the second summer of a plant H 109 crop. The graphs shown therein indicate the onset of rapid elongation in May as in this test. However, in the test referred to, there was no shortage of nitrogen imposed as a limiting factor and the growth proceeded at roughly constant rates from the latter part of May to the latter part of September. In this present variety experiment where rates were not constant, although temperatures and daylight hours were relatively similar to those of the former test, we feel safe in interpreting the results as the effects of a mild nitrogen deficiency. This nitrogen shortage is indicated in the downward trend of the total nitrogen of the top and green-leaf sections up to the November (sixth) harvest for all varieties. In the four-month, eight-month, and dry-leaf sections, there is also a strong downward trend in total nitrogen which persists through to the end of the crop, thus these sections differ from the upper stalk portions which, after November, show a gain in total and α-amino nitrogen, a condition which we interpret as a seasonal or weather-induced accumulation of relatively inactive physiological nitrogen fractions.

While growth rates (either by weight or elongation) show H 109 to be in the lead in the second summer, studies of total nitrogen percentages for the various age sections of the three varieties show no parallel wide differences in corresponding nitrogen contents except possibly in POJ 2878. The lack of real difference between H 109 and 31–1389 nitrogen percentages in first-order stalks arose from the fact that H 109 was forming larger volumes of primary stalk material, and any additional nitrogen taken up was perforce dispersed therein. On the other hand 31–1389 was also making secondary stalk growth and part of the nitrogen taken up was being diverted thereto away from primary-order stalks and, therefore, probably would not show any differences in the primary stalk analyses results.

Our interpretation of the inference in the above set of conditions is that sugar and nitrogen percentage indices *in primary stalks alone cannot be used to predict fertilizer requirements for a crop,* since it takes into account neither population per acre (or per foot of line), varietal population distribution in the stalk-age groups, nor the effect of the timing of fertilization itself on the latter, which we have shown to be quite important (3).

The use of an index drawn from a heterogeneous sample, of all ages of stalks which have millable cane, is also untrustworthy, as we have pointed out (2, p. 282), since it may indicate depletion of the nitrogen supply too late to avoid loss of growing time.

FIG. 32

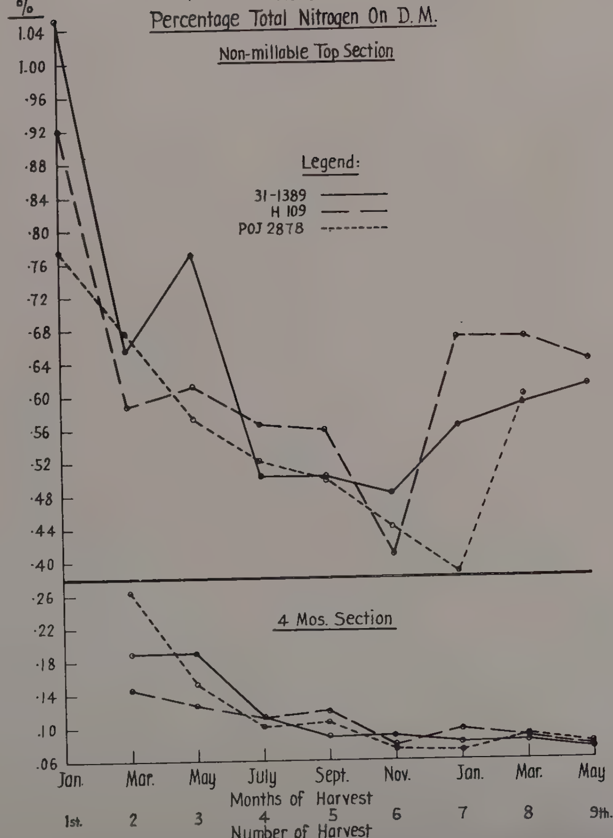
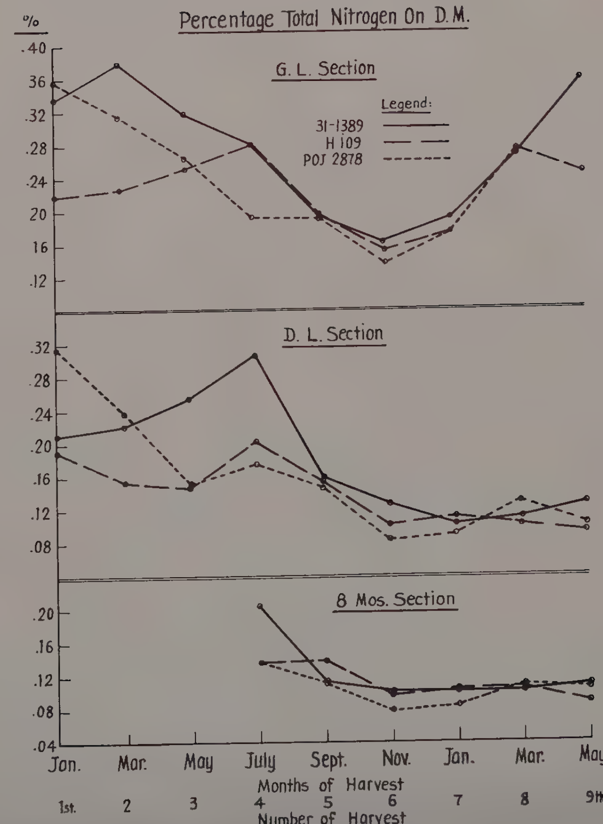

Percentage Total Nitrogen On D.M.
Non-millable Top Section
Legend:
31-1389
H 109
POJ 2878
4 Mos. Section
%
Jan. Mar. May July Sept. Nov. Jan. Mar. May
Months of Harvest
1st. 2 3 4 5 6 7 8 9th.
Number of Harvest

FIG. 33


Percentage Total Nitrogen On D.M.
G. L. Section
Legend:
31-1389
H 109
POJ 2878
D. L. Section
8 Mos. Section
%
Jan. Mar. May July Sept. Nov. Jan. Mar. May
Months of Harvest
1st. 2 3 4 5 6 7 8 9th.
Number of Harvest

The big problem to overcome in the control of nitrogen fertilization by means of sugar indices and nitrogen indices falls not so much in finding accurate index parts of the plant for use but in the interpretation and the application of these data to the crop. No index control system has been proposed which satisfactorily takes into consideration the following variables which affect our sample methods and the use of the data collected:

1. Population of stalks, and their relative age distribution in the field.

2. The soil nitrogen conditions, as they will be affected by season, location, prior treatment and weather (available and total N).

3. The prediction of weather, and the spectral type and amount of solar energy which will control plant activity during the remainder of the crop life after fertilization.

4. Varietal or genetic behavior, as correlated with the three foregoing variables.

5. How to correlate plant percentage data or absolute weight figures into the absolute pounds per acre figures necessary to apply fertilizer to the field. (This is a large problem in itself.) For an example of variable No. 1, in Figs. 3 to 7 is shown how widely the population-age of stalks may vary within three varieties. It is readily seen that data from first-order stalks of H 109 represent 65 per cent of the millable cane, but similar data from POJ 2878 are representative of less than half of the crop.

The influence of variable No. 2 has been found in a skirmish test, and data in the files at the Experiment Station indicate that there is a seasonal nitrogen cycle and a location effect influenced by light and moisture, as well as prior treatment, especially where carbohydrate material has been incorporated into the soil. Carbohydrates effect the fixation or loss of nitrogen through incorporation in soil microflora and microfauna activities.

As for Variable No. 3, prediction of solar energy, considerable work has been done on the effect of solar cycles in Canada and the United States and use is being made in Canada and Australia of sunspot data in the wheat-raising industry. However, no good correlations of spectral distribution and cane growth or sugar formation have been made, although there are air temperature and elongation correlations of value available. To date, no predictions for short-period weather, as influenced by solar cycles, are available. The entire fertilization program hinges on the solar energy (and local weather accompanying it) available for the crop period. The yearly ebb and flow of juice quality and cane tonnage of our crops under identical fertilization treatments should point to the validity of this statement.

Under the subject of varietal or genetic influences, Variable No. 4, falls not only tillering and tasseling influences but physiological behavior such as splitting, lalaing and, most important of all, the variable growth rates as influenced by chronological and physiological age. Illustration of these factors is evident in this experiment when we compare POJ 2878 and H 109 curves for the above mentioned characteristics.

The most complicated problem, Variable No. 5, involves the use of the data collected from the field sample. This brings up directly the problem of sampling or what may be taken as a criterion of the crop.

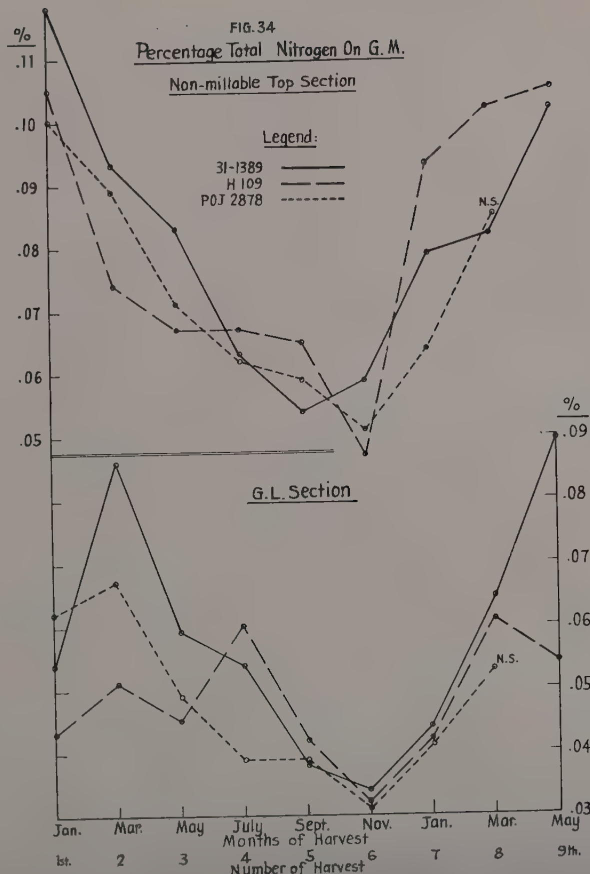


FIG. 34
Percentage Total Nitrogen On G. M.
Non-millable Top Section

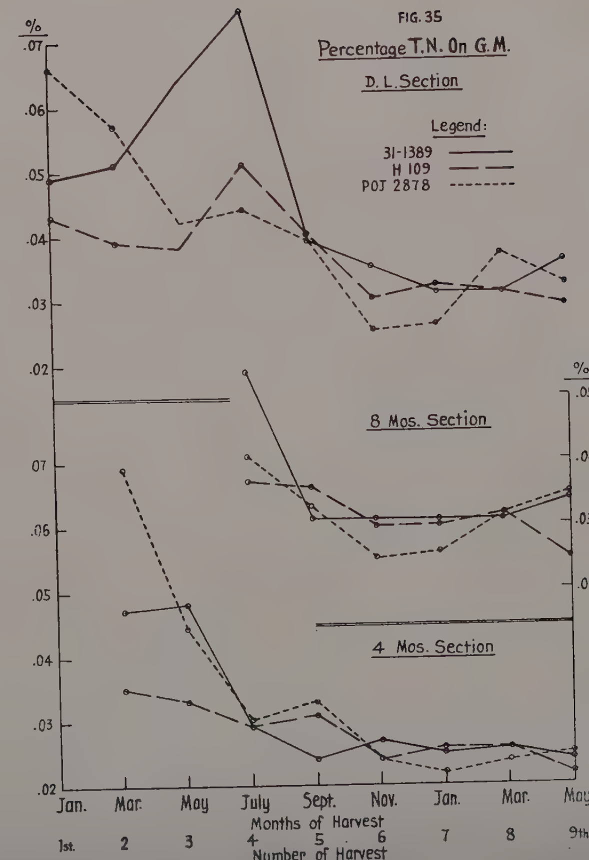


FIG. 35
Percentage T.N. On G.M.
D. L. Section

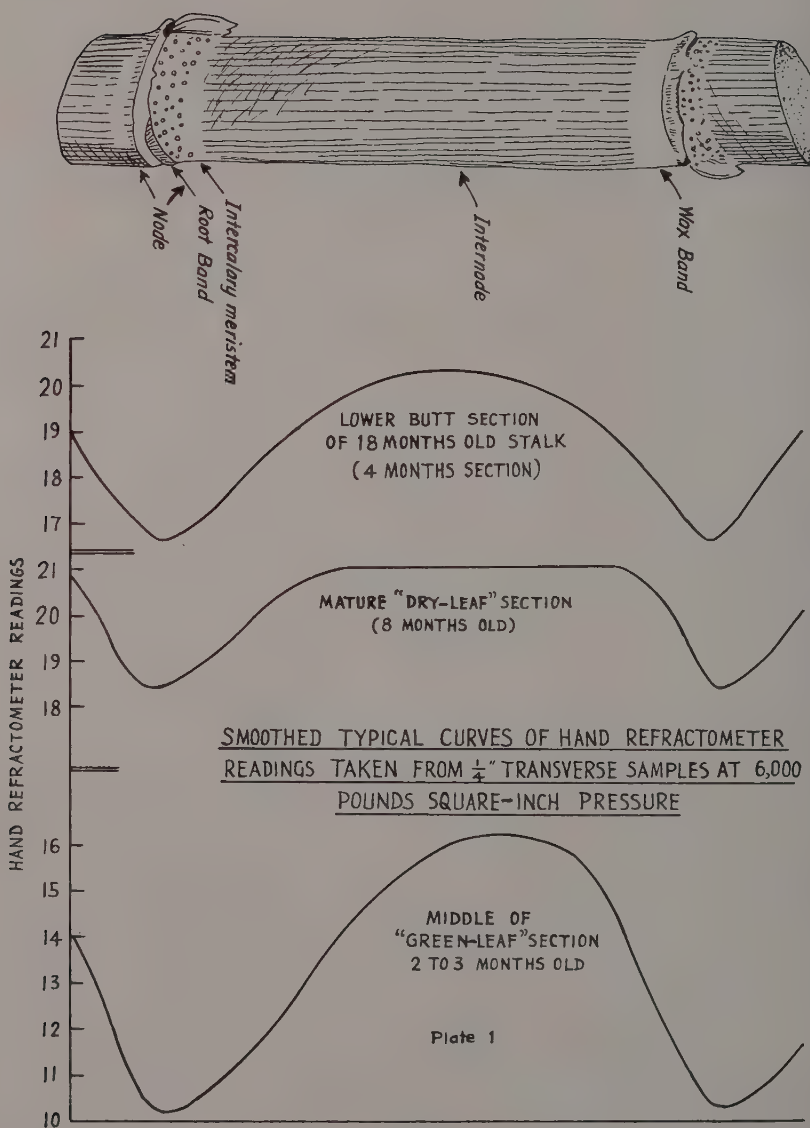
It is self-evident from the data in this paper that the selection of first-order or those stalks which carry large amounts of millable cane in the first year and which may be expected to live to harvest time, may well cause the non-inclusion of a considerable fraction of the crop made up of stalks (depending on variety and time of application of fertilizer) which will enter the millable stand in the summer of the second season. These secondary canes will be immature, poor in sucrose, high in water and salts, and will depress juice quality heavily if the field harvest is not delayed sufficiently for them to mature.

If this final maturity for secondaries is reached, mortality of primaries will be experienced in varying degrees, all controlled by the varietal responses to growing conditions. The confusing factor in taking any representative sample for index work is that after long years of cane growing and controlled experimentation, we have found that fertilization must normally be completed by the time the crop is chronologically about 12 months old and the secondaries to be found within this time, in our standard varieties, are not past the "sucker" stage of growth; thus perforce, any so-called comprehensive sample taken within the first 12-month period cannot possibly represent the final stand since it will volumetrically be influenced excessively by primary stalk conditions at sampling time.

Additionally, even though we were able to establish a satisfactory sampling procedure, our data would be expressed either in pounds (absolute) or percentage of the crop stand. To translate this percentage (or absolute pounds) of nitrogen in the plant into terms of pounds of nitrogen to apply to the soil involves as much empirical guess work as the whole fertilization program would entail, and would necessitate a long series of experiments on each soil type to determine its fixation, nitrogen loss, and rate of plant absorption, etc. To point out what happens to various amounts of nitrogen applied to a soil, attention is called to a paper by Dr. Das and the writer (5, p. 51, Fig. 2), and by Dr. Das (4). In the test referred to, we used three treatments: 133 pounds N/ac, 266 pounds N/ac, and 645 pounds N/ac applied in seven equal doses, the last dose going on by the fourteenth month. Nitrogen content of root tissue was not included in the calculations, yet in the low-nitrogen plot at eight months, we recovered 60 per cent more nitrogen than we had applied, while in the high-nitrogen treatment, we were never able to recover from the total aerial portions of plant material, 50 per cent of the amount applied. On the basis of pounds of nitrogen per acre recovered, the plots ranked in the order of amounts of nitrogen supplied, but by no means were the differences in nitrogen uptake proportional to the differences in the amounts applied. In other words, the efficiency of plant uptake (in pounds or percentage) bears little or no accurate relation to total pounds applied. In a previous article (3, p. 176) we discussed the uptake of nitrogen by the cane plant and pointed to the fact that the volume and age of plant material in the field controls largely the absolute amounts of nitrogen which will be recovered in the plant at any time.

In recent years there has been a tendency in the attempt to "streamline" crop control, to regard all variables, except the one studied or the one we are interested in, as being constants and, consequently, to either disregard them or touch on them only lightly in the reports.

We are not proposing a "defeatist" attitude toward the streamline idea in this discussion; we are merely trying to keep our feet on the ground, and to point out



SMOOTHED TYPICAL CURVES OF HAND REFRACTOMETER READINGS TAKEN FROM $\frac{1}{4}$" TRANSVERSE SAMPLES AT 6,000 POUNDS SQUARE-INCH PRESSURE

Plate 1

that we are still a long, long way from sufficient knowledge of fundamental sugar cane growth factors to apply an effective streamline control to even our well-known varieties, let alone to the new varieties constantly entering the picture. The results of this test, we feel, present arguments for this point which are worth considering.

Discussion:

The results of this test are not to be construed as showing more than varietal trends and to point out differences in behavior for which to watch in later tests of a more comprehensive nature.

As can be readily seen, the largest differences between the three varieties are in the timing and type of vegetative responses each exhibits with chronologic age. This in turn, influences cane yields, sugar yields, and the adaptability of a variety to our agriculture.

The vegetative responses referred to include all types of physiological differences which in many cases do not show as individual factors in graphs of final results. Some of these we did not measure due to lack of time; on others we gathered limited information through observation at various harvest periods. Such variables as length of internode, size of leaf, diameter of stick, size of non-millable top and leaf crown, mortality of small secondaries, and hardness of rind, all fall in this category. Without such observations many of the results graphed in this test would have been considered unexplainable and highly erratic.

The behavior of the percentage of sugars on dry matter, the percentage of dry matter in green matter, and percentage of sucrose in juice figures is a case in point. They looked impossible, but observation had told us that there were varying degrees of percentage of nodal material in the three varieties. To see what part this might have played in the data, we "quick froze" a full-grown stalk and sectioned it transversely in 1/4-inch sections. These we subjected to 6,000 pounds per square-inch pressure and took hand refractometer readings on the expressed juice. The resulting curves were plotted full scale for the 22-foot length of stalk (in files of Project D-1, Experiment Station, H.S.P.A. Library).

We have pointed out before that a cane stalk is a clone or made up of a community of individual plants and we have made the point that the composition of each joint or section of cane is influenced by growth conditions at the time of its formation, but we had little idea that each joint within itself would show such variability in positional concentration of solutes or that two internodes would give such unlike curves. At once, the question was opened as to corresponding fiber or dry-matter figures for the nodal portions as against the internode, and as to the relative percentage distribution of sucrose and reducing sugars in the two sets of tissues. It was decided to follow this lead in a succeeding test to be reported later.

It became evident at once that a large increase in the ratio of nodal to internodal tissue, due to slowing down of growth, would have considerable effect on sugar percentages on both the juice and dry-matter bases of calculation. This was immediately applicable in explaining the behavior of POJ 2878 in Figs. 20 to 24.

Although we ran only three stalks segmentally, it was evident that age tended to smooth out part of the node-to-internode differences by a build up of sugar content adjacent to the nodes, as well as in them.

The anatomical structure of a node and related internode also influences the

sugar concentrations, at least until the internode has stopped its elongation, and has practically ceased the translocation of most of its nitrogen from the node and adjacent tissue.

In Plate 1 it will be noted that nodal green-leaf material is some six degrees lower in refractometer reading than its adjacent internodes. There is a pronounced slope toward highest sugar concentration at a point somewhat above the center of the internode, which is to be expected due to the activity of the lower intercalary meristem area, and to the fact that the internode is "pushed up" from this intercalary meristem, and that the higher cells of the internode are thus older and more mature. The downward trend at the wax band is probably attributable to activity in the area just above it in the next node and to an apparent slight increase in fiber therein due to the initiation of branching (or anastomosus) of the vascular bundles in the top part of the wax band area.

When we pass to the dry-leaf section, the sugar concentration is more uniformly spread throughout the internode; and node-to-internode differences are much less. It will be noted that the slopes of higher sugar concentration have changed and spread downward toward the meristematic area. This is probably a reflection of the cessation of elongation activity at the meristem with its accompanying utilization of potentially storable sugars.

The top curve of Plate 1 is from stalk material at the butt of a mature stalk 18 months old. Here again there is an increased difference between node and internode sugar levels. The peak internode concentrations do not seem to have been disturbed in and about the center but there do seem to be decreases at the nodes. In this area, root primordia had developed to small aerial or adventitious roots in some cases, and may account for some of the loss although not by any means all, as the condition was present in sticks not so affected. We attribute the shape of the curve in this section to either catabolic or translocation losses, the movement being probably to the root system or to new shoots.

A question interposes itself, "To what node does which internode belong?" if such a division exists. In general the evidence would point to the node below as the one which most influenced the internode above in its development since the vascular system from the leaf attached to this node could feed the intercalary meristem tissues adjacent most easily. However, in actual practice, this does not hold for we stripped two adjacent leaves from such nodes early in life and found that we had not influenced the size of the internodes or the sugar contents in the least, so far as we could determine.

The sugar readings were taken when the cane was in the dry-leaf stage and the season of observation was the early fall of the second year. The stripping off of five leaves, however, did have a detrimental effect on both sugar concentration and growth of the stalk. From these short studies it would appear that a section of stalk is influenced by the conditions in the entire top rather than each leaf having its own integral special stalk volume to care for. In our case, the removal of two leaves did not seriously discommode the plant at its specific age and photosynthetic activity level: however, we are all familiar with the incidence of leaf diseases and their effects as illustrated in the general reduction in length, diameter, and sugar concentrations in stalk material which was in the growing stage when the diseases were effective. Quite definitely in these cases, the entire growing section is involved

rather than a single internode. Seasonal shortening of internodes is also sectional in effect.

A point of interest to note is that high on the stalk in the non-millable top portion the hand refractometer readings are highest for node tissue—just the contrary of conditions found eight or ten nodes below in the green-leaf portion and on down the stalk. The most readily accepted explanation is that actively operating leaves are attached at these nodes—feeding sugars through them at this stage to the rapidly elongating internodes which are consuming most of the sugars available for cell development. The nodal tissue, while immature, still is relatively more thoroughly developed or mature at this stage than the internode and has either a less, or slower, demand for sugar, or has more available than can be consumed immediately.

A few determinations were made for reducing sugar percentages, and also sucrose percentages, in the nodal and internodal tissues of the mature dry-leaf section on the dry-weight basis. While no statistical population was run, the evidence obtained seemed to point to higher percentages of reducing sugars in the internode, as well as higher sucrose content.

In the sucrose determinations, internode percentages to node percentages were as five to four, whereas in reducing sugars the ratios were two to one or three to one, indicating differences in rates of, or the types of, physiological function of reducing sugars in the two parts. The presence of apparently less reducing sugars in nodal tissue was frankly a surprise as microchemical studies had pointed to a considerably higher general nitrogen content of this tissue than in the internode proper. This nodal nitrogen was found most concentrated in the tissues of root primordia and under the lateral eyes. It was organic in composition, although whether of amino acid or protein forms, we cannot say. Based on our former findings that reducing sugars are present largely where nitrogen or protoplasmic activity is operative, we were led to the rough conclusion that the nitrogen present in the nodal tissues referred to above might be classed as "storage" forms (either to be used for eye and root growth or for translocation to more active centers) since it was not accompanied by excessive reducing sugar concentrations, i.e., α-amino acid forms.

Comparison of older with younger stalk material showed a definite reduction in nitrogen in the node with age, providing the apex bud was still alive and reasonably active. Translocation appeared to be indicated, but nitrogen catabolism in place could have achieved the same result and should not be disregarded. It was these anatomical observations that decided us to make a study, in the subsequent tests, of the sugars in the two classes of tissues.

Summary:

The data from this experiment indicate that there are small differences between varieties in concentrations of sugars, moisture and other plant constituents but that the largest differences between the varieties fall in the category of vegetative type and time responses.

Large differences in rates of growth, age-types of cane in the field, longevity of stalks, number of stalks, flowering habits and variable responses to weather are indicated. The vegetative differences influence the time of appearance and magnitude of the variations in concentration of the plant constituents at any time.

The wide variations experienced under identical conditions of growth indicate

that each variety must be studied for optimum fertilization, irrigation (and other treatments), and optimum harvest periods.

Special attention is called to the fact that the period of physiological maturity, rather than chronological age, will determine crop behavior in different varieties and is of utmost importance in determining the adaptability of a variety to the Hawaiian climate and cropping systems. The data point to the fact that varieties having short physiological life cycles and thereby poor "carry-over" qualities cannot be adapted to our harvesting schedules.

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In Tribute

It is with deep regret that we record the death of Motojiro Sadaiki, who passed away on March 4, 1944. Mr. Sadaiki was born in Japan on May 15, 1865 and came to Hawaii on the *Yamashiro Maru*. He landed in Honolulu in May of 1899 and was first employed at Ewa Plantation Company where he worked from 1899 to 1902. In 1902 he moved to the island of Hawaii and entered the employ of the Honomu Sugar Company where he remained until his death. In 1921, when Forestry Unit 3 was organized and tree planting in the Hilo Reserve began on an increased scale, the Honomu Sugar Company assigned Mr. Sadaiki to the work of planting trees within, and adjacent to, the Forest Reserve area. Motojiro was not a young man (56 years old) when he first began this work of planting trees but up to the end of 1943, when he was retired and placed on a pension, he remained active, going out into the field to work each day. His wants were few and easily satisfied. His work was his greatest interest in life. He had found his niche and enjoyed giving all he had to his work. In 1940 he thought of retiring but when he learned that the local Forest Supervisor was being called to active duty with the Army, he decided to remain at work, saying that "I do not feel that I can retire at this time."

During the twenty-two years that he was engaged in tree planting he established an enviable record. With very little assistance he planted out and cared for a total of 423,478 trees. Of course not all of these trees lived, but his technique and experience were such that a large percentage did survive and grow. They grew, and grew well, and today they can be seen in the distance, swaying in the trade winds and forming a living monument to one man who spent more than a score of years performing a job for which he was well suited and enjoyed doing.

(L. W. B.)

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
DECEMBER 16, 1943, TO MARCH 15, 1944

Date	Per pound	Per ton	Remarks
Dec. 16, 1943–March 15, 1944...	3.74¢	$74.80	Philippines